INTERNET 2017

The Ninth International Conference on Evolving Internet

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Nice, France

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Dirceu Cavendish, Kyushu Institute of Technology, Japan

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INTERNET 2017

Foreword

The Ninth International Conference on Evolving Internet (INTERNET 2017), held between July 23 - 27, 2017 - Nice, France, dealt with challenges raised by evolving Internet making use of the progress in different advanced mechanisms and theoretical foundations. The gap analysis aimed at mechanisms and features concerning the Internet itself, as well as special applications for software defined radio networks, wireless networks, sensor networks, or Internet data streaming and mining.

Originally designed in the spirit of interchange between scientists, the Internet reached a status where large-scale technical limitations impose rethinking its fundamentals. This refers to design aspects (flexibility, scalability, etc.), technical aspects (networking, routing, traffic, address limitation, etc), as well as economics (new business models, cost sharing, ownership, etc.). Evolving Internet poses architectural, design, and deployment challenges in terms of performance prediction, monitoring and control, admission control, extendibility, stability, resilience, delay-tolerance, and interworking with the existing infrastructures or with specialized networks.

We take here the opportunity to warmly thank all the members of the INTERNET 2017 Technical Program Committee, as well as the numerous reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to INTERNET 2017. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions.

Also, this event could not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the INTERNET 2017 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that INTERNET 2017 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in the field of the evolving internet.

We are convinced that the participants found the event useful and communications very open. We also hope that Nice provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful city.

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Inter-domain Routing Incentive Model Based on Cooperative Game

Donghong Qin[*†], Jiahai Yang[‡], Lina Ge[*], Zhenkun Lu[*]
[*]School of Information Science and Engineering, Guangxi University for Nationalities, Nanning China
[†]Department of Electrical and Computer Engineering, University of Massachusetts, Amherst, MA USA
[‡]Institute of Cyberspace and Network Science, Tsinghua University, Beijing China
Email: donghong.qin@gmail.com, yang@cernet.edu

***Abstract*—An incentive mechanism should be incorporated into the current inter-domain routing architecture because it can motivate Internet Service Providers (ISPs) to provide efficient and lasting routing services such as multipath routing and routing customization. In this paper, we model the cooperation and competition behavior of ISPs in the special inter-domain routing system (i.e., UMIR: user-customizing multi-path inter-domain routing), and then propose a novel incentive model based on cooperative-game. We abstract and give some basic concepts such as a routing coalition, sub-coalition and their characteristic function, and then design and develop a fair and feasible revenue allocation algorithm called shapely value algorithm. The theoretical analysis and experimental results show that this incentive model benefits the deployment of UMIR protocol and the formation and stability of a UMIR routing coalition. Therefore, it will push the UMIR network to evolve healthily and orderly.**

Keywords—Internet routing; user-customized multi-path inter-domain routing; inter-domain routing incentive model; cooperative game

I. INTRODUCTION

Currently the Internet hardly provides a routing service that assures the quality of service of various network applications, mainly because the Internet has not an efficient account & pricing function [1]. In the early days of the Internet, the U. S. government was uniformly responsible for the development and management of the ARPANET/NSFNET networks, at that time it was unnecessary for those networks to add the account & pricing function because this would decrease the technical or economic efficiency of the entire network [2]. Hence those initial networks are intrinsically shortage of the account & pricing function. Unfortunately, this function is hardly introduced to the current inter-domain routing architecture [3]. The shortage of the account & pricing function has brought up many challenges of the inter-domain routing, such as path expanding and performance degradation, and has also reduced the enthusiasm and initiative of the Internet Service Provider (ISP) for deploying newly routing protocols or service.

Generally, Internet traffic transmits multiple Autonomous Systems (AS) (for convenient expression, this paper alternates to use between AS and ISP) to arrive at a target network, where each AS is an independent and rational economic entity [4]. ASs with limited network resources must collaboratively transit their traffic with other peers, thereby accomplishing a globe-wide routing service. On the other hand, these independent and rational ASs would compete for their maximizing self-interests each other. In this paper, we consider the Internet routing as the routing game of all ASs, and then suppose that an AS would provide a special routing service and can obtain some economic revenue from stub networks or end users. For this goal, the AS needs other peer ASs to collaboratively provide the high quality of routing service. Therefore, how to model this inter-domain routing game and how to design the revenue allocation method among the Internet ASs will become two important challenges [5].

Our previous researches [6][7] have proposed a customizing inter-domain routing system called the User-customizing Multi-path Inter-domain Routing (UMIR), whose key principle is constructing a special Internet-wide AS-level topology to compute the Internet-wide one or multiple routes meeting user-customizing requirements. For some network users, the UMIR network not only improves their route-selecting flexibility but also meets their individualized routing requirements such as the multi-path routing and quality-of-service routing. However, the UMIR faces several challenges as following: First, since Internet paths available must be strategy-compatible, those paths with incompatible AS strategies will be of no avail even though they may have better performance. Second, although ASs deploy the UMIR protocol to improve their competitiveness, ISP would be not willing to do this without efficient incentive. Therefore, we in this paper propose a routing incentive mechanism for the UMIR network. The basic principle of this mechanism is as following: in the UMIR network, ISPs provide the multi-path routing or quality of routing services for network users that would pay extra fee; meanwhile, ISPs must allocate some revenue to other cooperative ISPs. Finally, this mechanism will motivate ISP to actively deploy the UMIR protocol.

The rest of this paper is organized as follows: Section 2 introduces the background of the UMIR network and the cooperative game; In Section 3, we provide a formal statement of the cooperative-game model of UMIR routing and have an analysis about the UMIR routing game and in Section 4 derive the revenue allocation method. In Section 5, we have carried on the experiment and given some performance evaluation. We conclude in Section 6 with a brief discussion of open problems and future works.

II. BACKGROUND

This section mostly introduces the basic principles of UMIR networks and the relative concepts of the cooperative game.

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A. UMIR networks

We have proposed a User-customizing Multi-path Inter-domain Routing (UMIR) [6, 7] whose main target includes (i) implementing the multi-path routing instead of the BGP single-path routing; (ii) meeting the routing requirements of network users about the route-selection flexibility and route-personalized characteristics. The UMIR-enabled networks are composed of multiple ISP agents deployed the UMIR system. In this network, AS nodes accepting users to customize the routing service are called as control node (CN), AS nodes including destination host or network are called as goal node (GN) and other AS nodes are called as cooperative nodes (CPs).

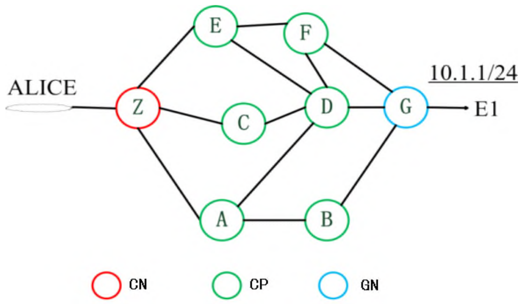

Figure 1. The simplified network (UMIR)

Figure 1 gives a simple example of UMIR networks. Alice is a network user (e.g., a stub network), and it hopes to customize a best-performance route destination to the network E1 from its ISP. This network is made up of UMIR-enabled agent sets {Z, A, B, C, D, E, F, G}, where Z is a control node, G is goal node and others are cooperative nodes. The control node (Z) creates a special network topology by collecting routing information from others cooperative nodes, and then compute and choose the best routes to the destination network E1 (10.1.1/24). In this network, the control node (Z) must request some route information from other cooperative nodes; correspondingly, the cooperative nodes can send their routing information to the control node. The routing information is called as the route-let which lists several important fields as following.

- PID—an identifier of the route-let information which is composed of two neighboring AS numbers.
- Prefix—a target network which is customized by a network user.
- Metrics—link performance vectors (e.g., bandwidth, delay, etc.) of the route-let.
- Type—an incentive model used in the UMIR network.
- Cost—some fee that the network user pays to the individual ISP.

In the UMIR network, users can customize the routing service to the target network from the UMIR-enabled ISP, and its control node initiates the UMIR computing process which constructs an Internet-wide AS-level topology to compute one or more best routes for the customizing user. Specifically, the UMIR process carries four steps as following:

- Customize the personalized routing service. Network users that need some special routing characteristics (e.g., low delay, high bandwidth) can pay their ISPs to purchase the customizing routing services. The ISP's control node will transform these characteristics of the user-customizing requirements into route profile parameters.
- Construct topology and compute the appropriate routes. According to the route profile parameters, the control node can construct an Internet-wide AS-level topology by requiring the route-let from other cooperative nodes, and then compute and choose best routes.
- Install the chosen routes. The control node will advertise every cooperative node to configure her individual data plane along the chosen path.
- Finish the settlement among relative ISPs. Since the control node (i.e., ISP) provides the customizing routing service for network users, these users must pay their ISPs with certain extra fee, in turn, which is allocated by the control node to other cooperative ISPs.

B. Cooperative game and its solutions

The cooperative game is a mathematical model used to describe the cooperation and competition behavior of rational entities, and study how to rationally make decisions in this environment [8, 9]. We utilize the cooperative game to describe the AS relationship in the UMIR network, and model the UMIR routing process as an AS cooperative game model. Each AS plays the UMIR cooperative-game by announcing the route information, and then all participating ASs will obtain certain economic revenue from this routing game.

The game solution is another challenge related to the cooperative game. Many experts of game theory have proposed a number of methods as for how to allocate coalition revenues. In the cooperative game, the allocation methods of coalition revenues are mainly classified into two categories [8]: dominant methods and valuation methods. Valuation methods have a unique allocation method for each cooperative game, which can balance some conflicting claims from various players and which can reflect the allocation equity and justice. The widely used valuation method is shapely-value method, because it has clearly economic implication and the simple calculation. Assume that there is a cooperative game CG=[N, v(S)], N=[1,…,n] and v(S) is the characteristic function of coalition S, which satisfies the axioms of symmetry, efficiency and additivity, the CG has one unique Shapely-Value as following:

$$\Phi(v) = (\varphi_1(v), \varphi_2(v), \ldots, \varphi_n(v))$$

$$\varphi_i(v) = \sum_{S \subseteq N} \frac{(n-|S|)!(|S|-1)!}{n!} [v(S) - v(S \setminus \{i\})] \quad (1)$$

Note that in (1), v(S) - v(S\{i}) shows the marginal contribution of the player i on the coalition S, if i does not

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belong to S, $v(S) - v(S\backslash\{i\})$ is zero, that is, the player does not have the marginal contribution toward the coalition S.

III. INTER-DOMAINS ROUTING UMIR GAME MODEL

This section firstly analyzes AS behavioral characteristics in the UMIR network by using the cooperative game, and then describes the AS survival scenario. Also, we discuss the rational basis to form a coalition and its stable conditions, and finally build a routing game model for UMIR networks.

A. *UMIR game*

Each AS of the UMIR network is a rational entity and can control its routing behavior to maximize its own revenue. Under the incentive routing scenarios, an AS declares the own routing information to participate in the routing game, and gets the corresponding revenue. In the UMIR network, an AS may be the control node or cooperative node, or both. On the one hand, ASs need their mutual cooperation to forward the Internet traffic and obtain some economic revenues; on the other hand, different ASs compete with one another to maximize their economic revenues. Thus AS survival scenarios are consistent with the player's of the cooperative game. Therefore, the inter-domain routing for the UMIR networks can be modeled by using the cooperative game, and the equilibrium outcome of the routing game is also gotten by the solution method of the cooperative game theory.

The cooperation game model of the UMIR routing network can be described as following: assume that exist the players set N= {1 ... n}, which is composed of n ASs and each AS is a rational player. The routing system will select a path (i.e., a routing coalition made up of the path's all ASs), and the coalition has also many sub-coalitions and each sub-coalition can define a characteristic function.

By using some terminology from cooperative game [8-10], we give some relative definitions in the routing game model.

Definition 1: Assume that for a routing game G = [N, *v*(S)], its players set N= {1, ..., n} consists of n ASs. If S = {i, | i is a certain AS along the selected path of a customizing user}, S is called as the routing coalition.

In the UMIR network, the member number of coalition S is far smaller than all player number N of this network, that is, $|S|<<|N|$. If the UMIR have selected a certain path, all ASs along this selected path will make up of a routing coalition.

Definition 2: Given a routing coalition S = {1,…, k}, for any set $M \subseteq S$, M is called as the sub-coalition of coalition S.

If M is allowed to take a null value and M = S is a routing coalition, and the number of sub-coalition M is $C_{k0} + C_{k1} + \ldots + C_{kk} = 2^k$.

According to the UMIR network in Figure 2, given the path L = z-c-d, there is a routing coalition S = {z, c, d}, whose sub-coalitions have {z}, {c}, {d}, {z, c}, {z, d}, {c, d}, {z, c, d}.

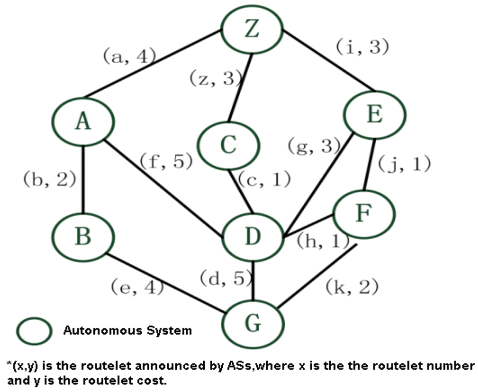

Figure 2. The example of the coalition revenue allocation

Definition 3: Given the routing coalition and its sub-coalitions, the characteristic function v(M) of any sub-coalition M is a mapping from the sub-coalition to the real number $v : M \subseteq S \rightarrow R$.

Definition 4: Call the game CG = [N, *v*(S)] as a UMIR routing game only if this game has following characteristics: (1) The players set consists of all ASs of UMIR network, namely, N = {1,…, k}; (2) For a routing coalition S, its sub-coalition M has the characteristic function *v*(M).

B. *Analysis of the UMIR routing game*

In the UMIR routing game, each cooperative ISP responses to the information request from the control node, and expects to be selected by the UMIR routing system (i.e., forming a routing coalition), which is a computing result of the routing system on the basis of the user route requirements and the current network resources. This coalition formation mechanism is determined by the internal and external demands of each participating ISP. An ISP's internal demand refers to its customer's personalized routing requirements, which urge it to deploy the UMIR-enabled system. If an ISP does not provide the customizing routing services such as multi-path or QoS routing, likely there rises the customer loss because of ISP's lower performance and competitiveness. An ISP's external demand means that it must consider its own economic interests as an independent and rational economic entity, thus an ISP must obtain certain benefits by providing extra and high quality routing services.

Once an ISP customizes the personalized path for a network user by participating in the UMIR-enabled network, that is, there will form a stabilizing routing coalition because there has an economic incentive. The main reasons are as following: (i) ISPs almost have large network resources so that their marginal cost of providing collaborative routing is very low and there easily form multiple various coalitions; (ii) As long as their participating coalitions are available, ISPs will obtain the economic benefit from these routing coalitions. These reasons will essentially strengthen the ISP's cooperation willingness, thus making the coalition more stabilizing.

The above analysis shows that, in order to motivate ISPs to provide stabilizing and lasting routing services, we must develop some mechanisms for the UMIR network to regulate and restrain AS behavior, including revenue allocation and coalition formation mechanisms. A routing coalition's formation is dependent on the user route requirements and existing network resources, which ensures that collaborative ASs have equally chance of being selected to provide the Internet routing service, i.e., it requires that the routing algorithm is fair and equitable. On the other hand, how to allocate the coalition revenue is a key problem solved for the coalition cooperative games. For UMIR networks, a revenue allocation mechanism is the basis of formation and stability of a routing coalition. In cooperative games, the revenue allocation is the solution of cooperative games, namely, how to allocate coalition revenue to each participating AS member fairly. For example, ASs can declare their routing-link information to the UMIR control node to participate into the routing game, if one AS is selected as the member of a routing coalition, it will obtain some expected revenue, and otherwise the expected revenue is zero. The AS expected revenue is a specific solution of routing cooperative games, such that the AS cannot change the link information to affect its due revenue. Only if all ASs obtain appropriate and reasonable revenue, the whole routing game will achieve an equilibrium solution, which is the Nash bargaining solution of cooperative games: if the UMIR networks exist Nash bargaining solution, no AS can obtain greater benefits by its self-declared strategy.

IV. REVENUE ALLOCATION METHOD

For the solution structure of the cooperation game, the Shapley value method has been widely used for its good economic meaning and simple computing [9]. This section describes how to design the coalition revenue allocation algorithm by using the basic principle of the shapely values method.

A. Sub- coalition and its characteristic function

The key elements of the shapely value method are the coalition definitions and the computing method of the characteristic function. In order to design an effective revenue allocation method, we must give the definitions of coalition and its characteristic function. According to Definition 1, the UMIR network forms a routing coalition by computing and selecting a concrete path, which this coalition is the result of multiple ASs routing game. The coalition members include all ASs along the selected path; moreover these ASs can further form a number of sub-coalitions.

By using a cost-plus pricing method [9] of the economics field, we give the definitions and computing expressions of characteristic function of the sub-coalition.

Definition 5: The characteristic function of the sub-coalition M is defined as sum of coalition cost and profit, and the computing expression is as follows:

$$v(M) = \sum_{i \in M} c_i + (q_0 - \sum_{j \in S-M} c_j) \qquad (2)$$

Where c_i is the cost of the member i, q_0 is the expected profits of a routing coalition, c_j is the cost of non-coalition member j. In Equation (2), the coalition revenue consists of two parts: the first item is the cost of all members in the coalition M, and the second item is the expected profit of coalition M.

By Definition 5, the sub-coalition revenue *v*(M) is the maximum benefit obtained from the coalition, and equals to the total cost of the coalition $\sum_{i \in S} c_i$ plus the difference between the revenues of coalition (q_0) and the cost $\sum_{j \in N-S} c_j$ of no- coalition members.

Below gives an example introducing the computing of coalition revenue. As shown in Figure 2, for the UMIR network, given the coalition S = {z, c, d}, need compute the revenue of two sub-coalition M_1 = {z, c} and M_2 = {z, c, d}. Assume the coalition revenue q_0 is the cost sum of the shortest path, namely q_0= 6, the sub-coalition revenue v (M_1) = 4 + 6 - 5 = 5, other sub-coalition revenue v (M_2) = 9 + 6 - 0 = 15.

B. A simple example

Section III has introduced the relative definition of a routing coalition and sub-coalition and the computing method of characteristic functions. We are going to discuss the revenue allocation method of SPA (Sha-Pley Apportionment). Assume the UMIR network uses one specific routing algorithm (e.g., BGP) to select a particular path according to user requirements, i.e., forming the routing coalition. The computing steps (see Figure 3) of the coalition revenue are as follows:

- **Initialization** that, given the coalition S, the expected revenue of its all members c_i ($1 \le i \le k$, k is a member number) and some initial system parameters.
- **ComputeSubcoalition** that determines the sub-coalitions in the coalition S, and the total number of sub-coalitions.
- **RevenueOfSubcoalition** that computes the revenue value of the sub-coalition M: for any sub-coalitions M, compute the revenue value of the sub-coalition by Equation (2).
- **RevenueOfeachAS** that uses Equation (1) to compute each AS revenue value in the coalition S.

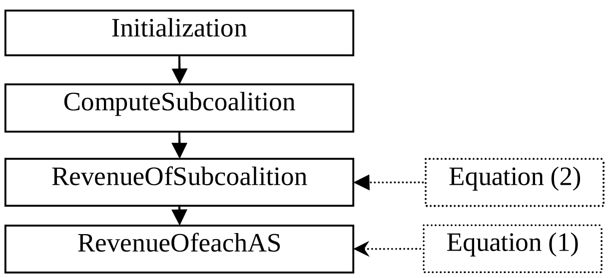

Figure 3. Flow chart of computing coalition revenue

Below we take Figure 2 as an example to show the computing process using the SPA algorithm. Assume a user want to customize the route from Z to G, and the control node selects the path {z-c-d} after running its path computing process, each AS revenue in the coalition S = {z, c, d} can be computed as following steps:

a) Given the coalition S = {z, c, d}, S has eight sub-coalition M such as Φ, {z}, {c}, {d}, {z, c}, {z, d}, {c, d}, {z, c, d}.

b) Compute the revenue of the sub-coalition M by the Equation (2), their result is showed in Table 1.

TABLE I. REVENUES OF SUB- COALITIONS

Sub-coalitions	Revenue
Φ	0
{z}	3
{c}	1
{d}	5
{z, c}	5
{z, d}	13
{c, d}	9
{z, c, d}	15

c) Compute the AS revenue of the coalition S by Equation (1):

$$v(z) = \sum_{\{i\} \subseteq S} \frac{(n-|S|)!(|S|-1)!}{n!} \quad [v(S) - v(S \setminus \{i\})]$$

$$= \frac{1}{3}(3-0) + \frac{1}{6}(4-1) + \frac{1}{6}(12-5) + \frac{1}{3}(14-8) = 4.67$$

Similarly,

$$v(c) = 1.67, v(d) = 7.67$$

d) All AS's revenues of the coalition S are: Φ(v) = (4.67, 1.67, 7.67)

Note: the AS's revenue of the UMIR network only depends on its contribution of coalition revenue. The further simulations will give the validation and comparison of the SPA algorithm. Moreover, AS revenues are independent of their places or positions in the coalition, because this characteristic is guaranteed from the symmetry axiom of the shapely value method [10].

V. EXPERIMENT AND EVALUATION

In order to testify the feasibility of our solution on the routing incentive model, we will do some experiments and have some analysis on the experimental results.

A. Simulation experiment

To evaluate the feasibility and effectiveness of several revenue allocation algorithms, we have developed a UMIR simulator [7] to carry out lots of experiments. The ASs are willing to participate in UMIR network with the incentive mechanism, so the experiments do not consider their business strategy and its impact on the routing selection results. Assume that the cost of AS inter-domain links complies with the uniform distribution of [10, 20], which refers to the spending cost that ISP forward or route user traffics (namely, it refers to the contribution under the cooperative routing).

We choose two allocation algorithms named the original average apportionment (OAA) and the cost weighted average apportionment (CWA) as two comparison algorithms. OAA is a simple average revenue allocation algorithm. And CWA is an improvement on the OAA algorithm, which considers the cost value of each coalition member during the routing game and which is based on the weighted cost size. Both algorithms do not consider the contribution of various members to the coalition. For the rational AS, OAA and CWA algorithms are unstable allocation algorithms, so they cannot guarantee to produce a stable and lasting routing coalition. However, the SPA algorithm is essentially a revenue allocation based on the contribution of coalition members, and therefore, it makes the routing coalition become more stabilizing and lasting.

The simulation experiment selects 1000 random AS node pairs (s, t) and runs the UMIR simulator where the selected routing algorithm is used to calculate the routing path of each AS node pair (s, t). And we evaluate the performance of SPA, OAA and CWA algorithms.

B. The result and theoretical analysis

Figure 4 shows the revenue allocation results of SPA, OAA and CWA algorithms respectively according to the participating AS with largest coalition contribution. For these AS nodes with big contribution of the routing coalition, SPA distributes the most revenue to them, CWA is the secondary and OAA is the minimum. For example, the data of No. 6 sample can be shown that for the greatest contribution in the coalition, SPA distributes the revenue of 41, CWA distributes the revenue of 36, and OAA distributes the revenue of 32.

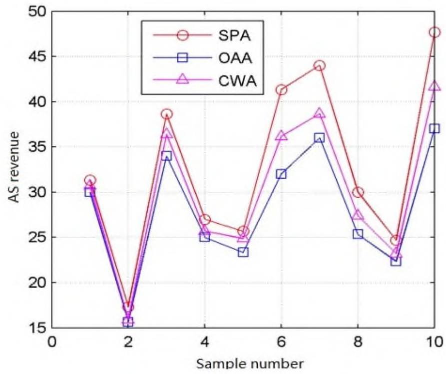

Figure 4. Comparisons of AS node with the most contribution degree

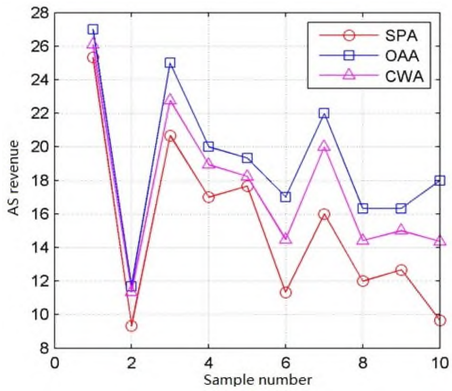

Figure 5. Comparisons of AS node with the less contribution degree

Figure 5 shows the revenue allocation according to the participating AS with the smallest coalition contribution. For AS nodes with smallest contribution, OAA distributes the most revenue, CWA is the secondary and SPA is the minimum. Therefore, compared with the OAA and CWA algorithms, SPA is one allocation algorithm based on the contribution, which benefits to the formation and stability of a routing coalitions.

Figure 6 shows the member revenue changes with total coalition revenue under the SPA allocation algorithm. With the total coalition revenue increases, the member revenue increases too. This is because the member contribution to the whole coalition has not changed, such that the member revenue will linearly increase with the coalition total revenue.

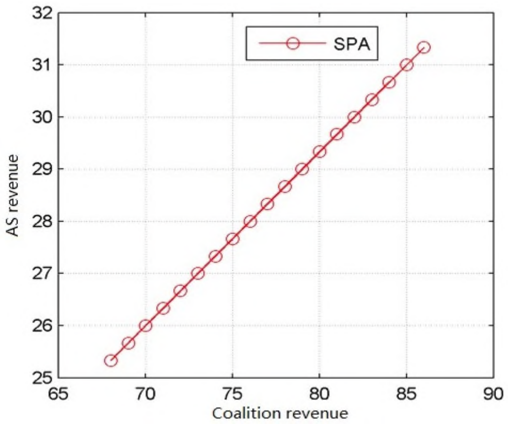

Figure 6. Influences of member revenue by coalition revenue change

As can be seen from experiments, the revenue allocation algorithm (SPA) is based on the contribution to the whole coalition routing, which provides a fair and equitable allocation for the coalition members. Therefore, our designed incentive algorithm can motivate ISP to improve the willingness for deploying the new UMIR protocol, and is helpful to produce a stabilizing and lasting routing coalition, thereby accelerating the healthy and orderly development of the UMIR network.

VI. CONCLUSION

The routing incentive is necessary to motivate ISPs to provide the efficient routing service in the globe–wide Internet, and then a fair and reasonable incentive scheme can benefit the cooperation between ISPs and maintain the Internet routing stability. In fact, there will be theoretical and practical significance as for how to use incentives to encourage ISP to deploy some efficient and valued-routing service or products. Based on the previous studies (i.e., UMIR), we had done the following studies in that paper: (1) analyze in detail the rational basis and stable conditions of a routing coalition formation in the UMIR network; (2) propose a routing cooperative game model for inter-domain routing; (3) design an efficient revenue allocation algorithm for the routing coalition. In the future work, we will verify the consistent ability of the ISP routing services, based on the routing performance from some monitoring facilities; and further, we will build the routing trust evaluation model to solve the deceptive announcements problem in the routing cooperative game.

ACKNOWLEDGMENT

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REFERENCES

[1] R. Feigenbaum, C. Papadimitriou, and S. Shenker, “A bgp-based mechanism for lowest-cost routing”, Proceedings of the twenty-first annual symposium on Principles of distributed computing, New York, NY, USA: ACM, 2007:139-150.

[2] V. Cerf and R. Kahn, “A protocol for packet network inter-connection”, IEEE Trans. Communications, 1974, 22(5):637–648.

[3] D. Clark, “The design philosophy of the DARPA internet protocols”, Proceeding of SIGCOMM'88, Palo Alto, CA, 1988:106-114.

[4] Y. Rekhter, T. Li, and S. Hares, A border gateway protocol 4 (BGP-4), RFC 4271, Internet Engineering Task Force, January 2006.

[5] H. Sam, Internet Routing Architectures (v2). Eastland, TX, USA: Cisco press, 2011.

[6] D. Qin, J. Yang, and H. Wang, “Multipath Inter-domain Routing via Deviation from Primary Path”, Proceedings of the International Conference on Information Networking (ICOIN2012), Bali, Indonesia, 2012:222-227.

[7] D. Qin, J. Yang, and H. Wang, “Another Multipath Inter-domain Routing”, Proceedings of the 26th IEEE International conference on Advanced Information Networking and Applications (AINA2012). Fukuoka, Japan, 2012:581-588.

[8] L. Petrosian, Game theory, Hong Kong: World Scientific, 2006.

[9] R. Gibbons, A primer in Game Theory. Princeton, New Jersey, USA: Princeton University Press, 2008.

[10] N. Nisan, T. Roughgarden, Algorithmic Game Theory, New York, NY, USA: Cambridge University Press, 2007.

[11] M. Afergan, “Using repeated games to design incentive-based routing systems”, Proceedings of 25th IEEE International Conference on Computer Communications, Barcelona, Spain, 2006:1-13.

[12] M. Afergan and J. Wroclawski, “On the benefits and feasibility of incentive based routing infrastructure”, Proceedings of the ACM SIGCOMM Workshop on Practice and Theory of Incentives in Networked Systems, Portland, OR, USA: ACM Press, 2009: 197-204.

[13] N. Nisan and A. Ronen, “Algorithmic mechanism design” ,Games and Economic Behavior, 2002: 35(1): 359-379.

[14] R. Cominetti and C. Guzmn, “Network congestion control with Markovian multipath routing”, Mathematical Programming, 2014, 147(1-2): 231-251.

[15] J. John and M. Therese, “Traffic Light Based Multipath Routing Mechanism for Non-Geostationary Satellite IP Networks”, Traffic, 2015, 2(2).

[16] J. Zhang, D. Zhang, and K. Huang, “Improving Datacenter Throughput and Robustness with Lazy TCP over Packet Spraying”, Computer Communications, 2015.

[17] V. Shuvalov and I. Varaksina, “Estimation of control errors influence on availability of multipath routing system”, 2014 12th International Conference on Actual Problems of Electronics Instrument Engineering (APEIE). IEEE, 2014: 420-426.

Verification of Openstack Operation with Normality-degree of Workflows

Ryota Mizutani, Takeshi Usui, and Yoshinori Kitatsuji
KDDI Research, Inc. 2-1-15 Ohara, Fujimino, Saitama, 356-8502 Japan
E-mail: {ry-mizutani, ta-usui and kitaji}@kddi-research.jp

***Abstract*— Verifying job executions in operating virtual networks has emerged as a crucial issue for network operators. Now, tracking and monitoring log messages of the operations is a typical approach. However, a monitoring system to detect a critical operation is based on text matching with the previously obtained log messages indicating normal operations. It basically has a limitation that similar but different log message flows become indeterminable to judge the normality of the operation. We propose a solution that estimates the normality-degree for the indeterminable log message flows. We evaluate the difference in normality-degrees between normal and abnormal completion message flows. We show that the proposed method distinguishes these cases more clearly than the conventional method. This indicates that the proposed method enables the system administrator to classify job execution into three types (i.e., normal, semi-normal, and abnormal completions). As a result, the proposed method allows the system administrator to focus on critical job executions in troubleshooting operations.**

Keywords-NFV; Openstack; Log message; Normality-degree; Similarity-degree

I. INTRODUCTION

The rapid spread of virtualization technology [1] has motivated network operators to procure communication service systems consisting of network function virtualization (NFV) [2][3]. NFV allows network operators to deploy network functions on the virtualized infrastructure where the physical entities (switches, routers and servers) provide a virtual (logical) network composed of logical links, routers and servers (called virtual links, routers and machines, respectively). In general, the logical entities are realized by software programs. In addition, the network topology of the virtual network is not identical to that of the physical entities that compose the individual logical entities.

Openstack [4] maintains the virtual networks (i.e., to create, initiate, terminate and delete virtual machines and to manage the virtual network with them). Because the major network providers (AT&T [5], Deutsche Telekom AG [6], Rackspace Cloud [7], and so forth) have adopted Openstack, it is the de-facto standard for virtual network management systems in commercial.

Openstack is composed of multiple function blocks (e.g., Neutron, Nova, and Cinder described in Section II), and the function blocks are composed of multiple service processes, e.g., an interface to other function blocks, a scheduler for tasks initiated by arrival requests, and individual major processes. The service processes run independently (in a parallel manner) in the function block.

Openstack executes jobs, e.g., creates, initiates, terminates and deletes virtual machines, with these entities. To verify whether the jobs are normally executed or not, the system administrator tracks the log messages produced by the service processes. However, this procedure is often complicated, because Openstack inherently assigns no job identifier to the log messages, and the series of log messages obtained by the system administrator become scrambled over the function blocks. Then, it is difficult to verify job completions by simply tracking the log messages.

Regarding the result of job executions, there are three types of normality judgements: normal, semi-normal, and abnormal completions. A normal completion implies that the job completes successfully without any problem. A semi-normal completion implies that the job eventually completes although there are some problems, typically, a long delay. An abnormal completion implies that the job actually does not complete as a designed procedure. Regarding Openstack, each kind of job completions has various sequences of log messages (referred to as workflows). It is because the orders of function blocks and service processes vary, and consequently the orders of their log messages result in varying.

A typical judgement of job executions involves matching the current workflow with previously given workflows (referred to reference workflows) with normal, semi-normal and abnormal completions. The system administrators cannot comprehensively assess all the workflows. Therefore, the monitoring of job executions (workflows) eventually encounters indeterminable judgements in the case where the workflow does not match any of those previously given. We refer to this workflow as an indeterminable workflow.

To identify an indeterminable workflow in the normality judgements, several similarity algorithms have been used. The text matching rate is used to identify an indeterminable workflow to the reference workflow [8]. Text matching utilizing the TD-IDF is employed to diagnose anomalous patterns [9], and cosine similarity is used to detect traffic anomaly deviations [10]. These researches identify the indeterminable workflow in the most similar unique reference workflow. Though, these methods disables to normal identification if there are no reference workflow (i.e., unknown anomaly).

To tackle this identification issue, we propose a method that utilizes similarity estimation adopted in string-pattern matching. The similarity estimation rates differ between two strings expressed by three differences types: addition, deletion, and displacement of string portions. We express a log message as a symbol of a string, and a workflow as a string. We estimate the similarity between workflows in

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order to express the normality-degree of the job execution. We evaluate the difference of normality-degrees between log message flows with normal, semi-normal and abnormal completions. The result reveals that the proposed method can distinguish the above three cases more clearly than the conventional method.

The rest of the paper is organized as follows. In Section II, we introduce the issues associated with normality estimation regarding the log messages in Openstack. In Sections III and IV, we propose and evaluate the method of normality estimation. In Section V, we conclude this paper.

II. ISSUES ENCOUNTERED WHEN ESTIMATING FAULTS FROM A WORKFLOW

This section gives an overview of Openstack and workflows, and the issues encountered in the operational flow with Openstack, especially in the area of troubleshooting with accumulated indeterminable job executions.

A. Overview of Openstack and Workflows

Openstack has multiple function blocks that manage virtual resources (e.g., memory and CPU) provided by the physical entities. The primary function blocks are Nova, Neutron, Cinder, Swift, Glance, Keystone, and Horizon. Nova builds the virtual machines and routers [8]. Neutron sets up links between the virtual machines and routers and manages basic configurations (e.g., IP address assignments, and topologies). Cinder manages block storages for virtual machines and routers. Swift manages the configuration templates for setting up the multiple virtual machines simultaneously. Glance provides OS images for virtual machines and routers. Keystone provides an authentication service corresponding to the job executions. Horizon provide user interfaces, typically with graphical user interfaces.

Each of the functions has single or multiple dedicated service processes. The service processes run dedicated tasks and each task produces log messages. For instance, when the virtual system administrator commands the creation of a virtual network, a command signal originates from Horizon (the user interface), and is sent to Keystone (for authentication), Nova and Cinder (building virtual machines), Glance (installing OS), and so forth.

Generally, Openstack is composed of several physical or virtual servers. These servers have different roles. For example, the controller server has a management role and requests job execution to the control servers. The computer server provides the resources (CPU, memory, storage, and so forth) with a virtual machine.

A major reason for workflow variations is that some function blocks execute multiple service processes, and request tasks to the other function blocks in parallel. This leads to addition, deletion, and displacement of portions of log messages in the workflow. Fig. 1 shows samples of a variety of workflows. In this figure, the characters represent a single line log message. These three patterns are the most

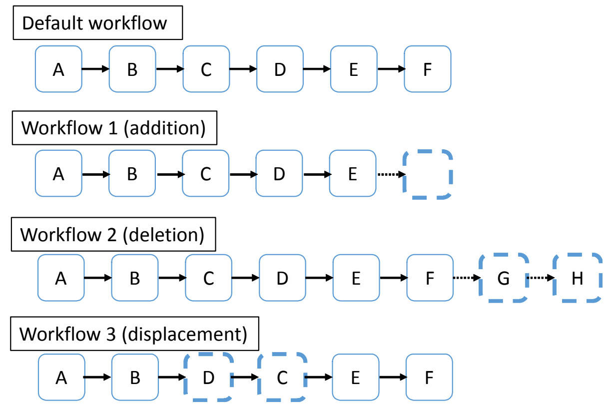

Figure 1. Samples of a variety of workflows

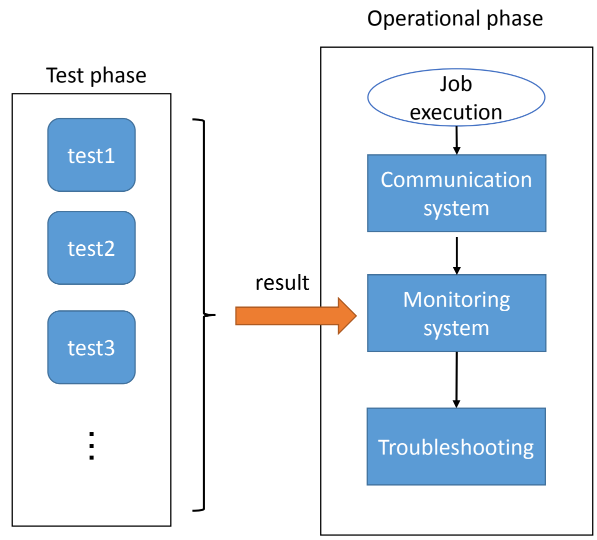

Figure 2. Flow of communication system operation.

typical pattern variations. We assume the default workflow is the most frequent pattern that is generated when executing a job. One is addition. In workflow1, the character “F” needs to be added to correspond the default workflow. Another is deletion. In workflow2, the character “G” and “H” need to be deleted to correspond to the default workflow. The other is displacement. In workflow3, the character “C” and “D” need to be displaced to correspond to the default workflow.

Fig. 2 illustrates the generic flow of communication system operation. The communication system has the feature of continuously providing its communication services. The system operational phase follows the test phase.

The test phase improves the completion of development before the communication system starts to provide its communication services. This phase comprehensively tests all the designed processes of the system, (or as many as possible) to remove bugs remaining from the time of its development. Some of the tests should be for all job executions, and are used for the monitoring system in the operational phase.

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TABLE I. JUDGEMENT CASES PROVIDED BY MONITORING SYSTEM ESTIMATING NORMALITY WITH WORKFLOWS PREVIOUSLY GIVEN: SIMILAR/DIFFERENT PATTERN TO/FROM THEM.

		Workflows previously given	
		Workflows with normal completion	Workflows with abnormal completion
Judgement of a new job execution	Similar pattern	Case *A*	Case *B*
	Different pattern	Case *C*	Case *D*

In the operational phase, however, they are initially not enough because of the workflow variations. We conjecture that a monitoring scheme takes exact-matching of workflows. This results in indeterminable completions occurring when monitoring job executions in the operational phase. This would tend to be a large number, especially in the initial period. As the operational phase proceeds, the indeterminable workflows should decrease as a result of providing the judgement results (normal, semi-normal and abnormal completion) revealed by troubleshooting of the monitoring system. The given workflows and their judgements are referred to as reference workflows, hereinafter.

A significant issue is that it takes a long time to remove potentially critical elements in the communication system. Actually, it is not clear which indeterminable completion the system administrator should focus on among the accumulating completions, in troubleshooting operations. They may include critical job executions, and a system failure will occur before long. Our challenge is to prioritize them according to the criticality of the indeterminable workflows.

Table I illustrates the judgement cases and the reasons that provided by monitoring system. This is based on the job executions with workflows previously given. The columns are types of execution results belonging to workflows previously given: normal and abnormal. The rows represent the similarity/difference to/from the given workflows under the assumption that the monitoring system can estimate normality.

When the monitoring system judges that there is a new job execution with indeterminable completion, there are four possible combinations in terms of given workflows with normal or abnormal completion: AB, AD, CB, and CD. Case AB implies that the workflow of a new job execution is similar to the workflows previously given with both normal and abnormal completions. In this case, one of the workflows previously given could be wrong, or they may just be similar (in other words, this implies that normality estimation is difficult). In the case of AD or CB, the results are probably correct, i.e., the results are likely to be normal or abnormal completions in the cases of AD or CB, respectively. Case CD implies that the monitoring system has identified no effective workflow preliminarily given.

It is desirable that troubleshooting for indeterminable completions first deals with case CB (almost certainly abnormal), and cases AB (one of the given workflows is possibly wrong), CD (no reference to estimating normality), and AD (almost certainly normal) in this order. Our challenge is how to estimate similarity degree among multiple workflows previously given, in order to prioritize the job executions with indeterminable completions for troubleshooting. The next section describes the proposed method that solves this challenge.

III. PROPOSED METHOD

In this section, we propose a solution for estimating normality-degree for the indeterminable workflow of job execution. We first give an overview of definition of normality-degree, second, an algorithm for normality-degree is presented, and third, a method for judging normal, semi-normal and abnormal completion is described.

A. Overview of Normality-degree Estimation

We provide an overview of the process employed in the proposed method. First, the system administrator collects the reference workflows (how the jobs have been completed: normal, semi-normal and abnormal completions) from the job execution results. Second, the proposed method uses a string-similarity evaluation method (evaluation of addition, deletion and displacement of two strings) in order to measure the similarity of workflows between the indeterminable workflows and reference workflows. Third, the normal distribution of the similarity of workflows is calculated in order to distinguish normal, semi-normal and abnormal completions more clearly. Finally, the proposed method estimates the normality-degree using the normal distribution, as described in Section III-C.

The normality-degree represents how closely the indeterminable workflows correspond to the reference workflows. As described in Section II-C, the system administrator uses the normality-degrees as a reference to select a particular job execution with indeterminable completion from among many for troubleshooting.

B. Proposed Method Expressing Similarity of Reference Workflows

This subsection describes the preliminary process in three steps: workflow construction, similarity measurement, and forming a similarity distribution regarding normal, semi-normal and abnormal completions.

1) Workflow Construction

In the test and operational phase, the workflows are obtained from the continuous generation of log messages. In the test phase, the log messages are compiled while a series of tests are conducted. In the operational phase, the system administrator performs multiple job executions. First, the system administrator must decide how to divide log messages into multiple sets of messages according to the individual job executions

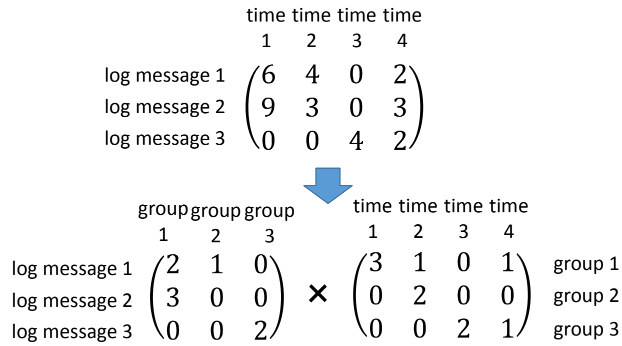

Figure 3. Sample of NMF utilization

TABLE II. RELATIONSHIP BETWEEN LOG MESSAGE TYPE AND CORRESPONDING CHARACTERS

Log message type	Corresponded character
INFO nova.osapi_compute.wsgi.server [admin admin] ... "GET /.//flavors/ HTTP/." status: len: time: .	A
INFO nova.osapi_compute.wsgi.server [admin admin] ... "GET /.//images/ HTTP/." status: len: time: .	B
INFO nova.compute.claims [admin admin] [instance:] Claim successful	C
INFO neutron.agent.securitygroups_rpc [None None] Refresh firewall rules	D
INFO neutron.plugins..drivers.openvswitch.agent.ovs_neutron_agent [None None] Configuration for devices up [] and devices down [] completed.	E
INFO nova.compute.manager [None None] [instance:] VM Started (Lifecycle Event)	F
INFO nova.compute.manager [None None] [instance:] VM Paused (Lifecycle Event)	G
INFO nova.compute.manager [None None] [instance:] During sync_power_state the instance has a pending task (spawning). Skip.	H

The naive method to divide log messages generally uses the identifier assigned to the log messages indicating which job execution produces [9][10]. However, Openstack assigns a unique identifier to log messages related not to a job execution but a function block. This implies that the log messages can only reveal which function block causes a problem when log messages indicate an error or warning. We utilize a non-negative matrix factorization (NMF) [11][12] that divides log messages into multiple groups. This method can divide a mixture of data sets with counter attributes into multiple groups by reasonably distributing the values of counters into the formed groups [13]. The proposed method utilizes NMF to obtain two benefits: one is dividing log messages into workflows, and the other is deriving the number of workflows. Fig. 3 gives an example of results obtained by utilizing NMF. The original matrix presents the number of log messages for every time unit (e.g., every ten seconds). NMF divides this matrix into two matrixes: one is the number of log messages belonging to the workflow (denoted by ‘group’ in Fig. 3), and the other is the number of workflows (groups) in every time unit. In dividing a matrix, the original matrix is represented by the two smaller matrices, which, when multiplied, approximately reconstruct original matrix. To apply NMF to the log message, we use Table II to classify the log messages depending on the contained messages and service block IDs, job types, and signal types.

NMF still needs a heuristic approach to provide a substantial number of data sets divided into the particular groups. In the proposed case, we give the number of workflows sequentially, and find the appropriate number of the workflows where the difference between the original matrix and the multiplication of two divided matrixes (the summation of the mean square error of matrixes’ elements) is below a threshold obtainable by scanning the number of workflows.

2) Similarity Measurement

After obtaining the reference workflows, the proposed method tries to find any trends in workflow similarity. Specifically, it estimates the degree to which sequences of log messages are identical in terms of their length, and displacement.

The proposed method takes the concept from the similarity-degree evaluated by Jaro distance [14], which measures the string similarity based on the number and order of the common characters. It is generally utilized in order to identify typos and spelling mistakes in sentences. This algorithm computes a similarity score normalized between 0 to 1 where 0 indicates no similarity and 1 indicates an exact-match. Jaro distance D between two strings X and Y (difference between ASCII codes) is defined as:

$$D = \begin{cases} 0 & \text{if } m = 0 \\ W_1 \times \dfrac{m}{L_X} + W_2 \times \dfrac{m}{L_Y} + W_3 \times \dfrac{m-t}{m} & \text{otherwise} \end{cases} \quad (1)$$

where m and t denote the number of matched characters, and the number of displacements, respectively. L_x and L_y denote the character lengths of strings X and Y, respectively. Three coefficients, W_1, W_2, and W_3, are weights in the following ranges: $0 \leq W_1 \leq 1$, $0 \leq W_2 \leq 1$, $0 \leq W_3 \leq 1$, and $W_1+W_2+W_3=1$.

The first and second terms compute ratios of common characters in terms of strings X and Y. The third term computes the ratio of displacement against the common characters. No matter where the common characters are positioned in the strings, it is counted as m. For example, when two strings X=’abcd’ and Y=’abdec’ are given, the similarity score D is about 0.77 in the cases of W_1, W_2, and W_3 for 1/3. The first and second terms of (1) can be seen as the ratios of common characters in terms of strings X and Y.

When strings X and Y are identical, the first and second terms, respectively should be 1. When string X is longer than string Y (this implies that string X has more uncommon characters more than string Y), the first and second term should be low and high, respectively. Additionally, when the strings X and Y are switched, the values of first and second terms also switch

In order to apply this to workflows, first, we utilize the correspondence table shown in Table II in order to denote the workflows as the strings. Second, we treat three terms of (1) separately, as follows:

$$D_1 = \begin{cases} 0 & \text{if } m = 0 \\ \dfrac{m}{L_X} & \text{otherwise} \end{cases} \quad (2)$$

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$$D_2 = \begin{cases} 0 & \text{if } m = 0 \\ \dfrac{m}{L_Y} & \text{otherwise} \end{cases} \quad (3)$$

$$D_3 = \begin{cases} 0 & \text{if } m = 0 \\ \dfrac{m-t}{t} & \text{otherwise} \end{cases} \quad (4)$$

where variables X, Y, m, t, L_X, and L_Y are the same as those used in (1). Equations (2) and (3) evaluate the ratios of common log messages in terms of the two workflows X and Y, and (3) evaluates the ratio of displacement of the common characters. In the following discussion, we refer to D_1, D_2, and D_3, as addition, deletion and displacement scores, respectively.

3) Expressing the population of workflows

The step in this subsection derives the probability density regarding the normal, semi-normal, and abnormal completions in the reference workflows to express the population of the reference workflows. First of all, we surveyed the workflows obtained from various job executions, and found that almost all the reference workflows are different from each other, but there are many similar patterns of log messages for each of normal, semi-normal or abnormal completions. Additionally, there are few pairs of workflows that are markedly different from the similar log message patterns of workflows. Therefore, we conjecture that a normal distribution can reasonably express the population of the workflows.

Actual computations are used to derive the normal distributions for the addition, deletion, and displacement scores for each of the normal, semi-normal and abnormal completions. For this, the proposed method computes the averages and variances of the addition, deletion and displacement scores. These probability densities are used to estimate the normality-degree of the indeterminable workflow that occurs in the operational phase, as described in the next subsection.

The computation of the averages and variances takes all the pairs of workflows in the reference workflows. Because the addition and deletion scores can switch when the compared workflows switch, these scores should have an identical average and variance. Each normal distribution for addition, deletion and displacement is represented by:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right) \quad (5)$$

where $f(x)$ is a function of probability density, μ is the average of the similarity scores, and σ^2 is the deviation of the similarity scores. Fig. 4 shows some examples of three probability densities for the addition (D_1), deletion (D_2) and displacement (D_3) scores for workflows with normal completion.

This derivation of probability density is conducted for each of the semi-normal and abnormal completions in order to estimate the normality-degree, as described in the following subsection

C. Estimation of Nomality Degree

In order to estimate normality-degree, we propose products of the derived probability density from the addition, deletion and displacement scores.

The naive approach can be employed to utilize the similarity-degree measurement algorithm directly. However, it has some difficulties when two or more differences occur in the similarity computation where two or all the terms in (1) are affected. Actually, no pair of workflows are identical, and all the terms become less than 1, and similarity D of (1) cannot clearly show the difference.

We show the steps for estimating the normality degree. First, we collect the indeterminable workflows and calculate the three types of similarity between the reference workflow and indeterminable workflow derived from (1)-(3) in the operation phase. This step is the same as that done in the test phase described in section III-B. Next, we obtain the probability density by substituting the similarity into a normal distribution (5). Finally, the proposed method (products approach) simply multiplies each probability density derived from (5) for the addition, deletion and displacement scores. We regard this multiplied value as the normality degree. As shown in Section IV-B, the results clearly showed the difference (or fitness) to the judgement of the indeterminable workflows. We take probability density into account because we found that almost all the reference workflows are different from each other, but there are many similar log message patterns for each of the normal, semi-normal and abnormal completions. Additionally, there are few pairs of workflows that are markedly different. Therefore, we conjecture that the normal distribution can reasonably express the population of the similarity.

IV. EVALUATION

This section evaluates the distinguishability of the normal, semi-normal and abnormal completion workflows identified using the proposed method by comparing the conventional approach with the product approach. First, we describe the environment from which we obtained the log messages; secondly, we show the evaluation result.

A. Evaluation Environment

We obtained the log messages from the evaluation environment. We adopted Mitaka [15] as the version of Openstack, and set up a single pair of controller, computer and log servers. Each server has Ubuntu 16.04 as its operating system, a CPU with 12 cores, and 32GB of memory. The log server collects all the log messages generated in the controller and computer servers, and merges them into a single file.

In order to construct the reference workflows, we selected “VM creation” as an example of job execution. The created VM was assigned a single virtual CPU and 2 GB of memory. A hundred VM creations were included in the reference workflows.

To evaluate the performance of our proposed method, we prepared ten indeterminable workflows for the three use cases, as follows.

TABLE III. MAXIMUM AND MINIMUM NORMALITY-DEGREE WHEN USING COSINE DISTANCE

	use case 1	use case 2	use case 3
max	1.000	0.897	0.632
min	0.917	0.688	0.381

TABLE IV. MAXIMUM AND MINIMUM NORMALITY-DEGREE WHEN USING JARO DISTANCE

	use case 1	use case 2	use case 3
max	1.000	0.944	0.769
min	0.827	0.750	0.481

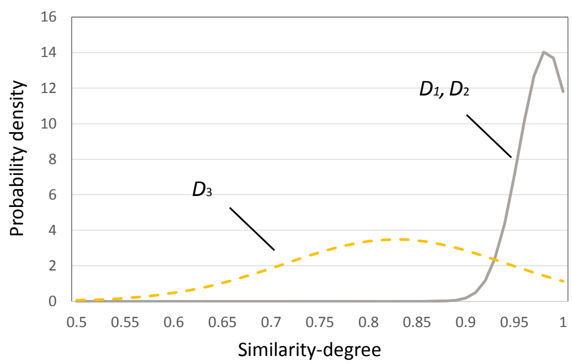

Figure 4. Distribution of probability density of normal workflow

[Use case 1] Normal completion: This is an example of normal completion of job executions.

[Use case 2] Overload: This is an example of semi-normal completion of job executions. When one function block in Openstack sent a signal to another block, we made a message queue with excessive traffic, and it causes signal losses.

[Use case 3] Network down: This is an example of abnormal completion of job executions. We shut down the interface of the computer server connected to the controller server. That interface was mainly used to send Openstack operational signals.

B. *Evaluation result*

We verified the performance of the proposed method described in Section III. First, we show the similarity-degree between the reference workflow and the three use cases of indeterminable workflows. Table III shows the maximum and minimum normality-degree when using cosine distance. Table IV shows the normality-degree when using Jaro distance (1) with coefficient for 1/3 is used. We define this similarity-degree calculation method as the conventional approach. Our purpose is to distinguish among the three use cases. If the difference in the normality degree of the two use cases is large, there is a high possibility that the two use cases can be distinguished. Tables III and IV show that the difference for each use case is low, and it confirms that it is difficult to distinguish the use cases. Next, we derived the

TABLE V. MAXIMUM AND MINIMUM NORMALITY-DEGREE WHEN USING PRODUCT APPROACHES

	use case 1	use case 2	use case 3
max	1.000	0.567	7.02E-05
min	0.919	0.110	1.33E-09

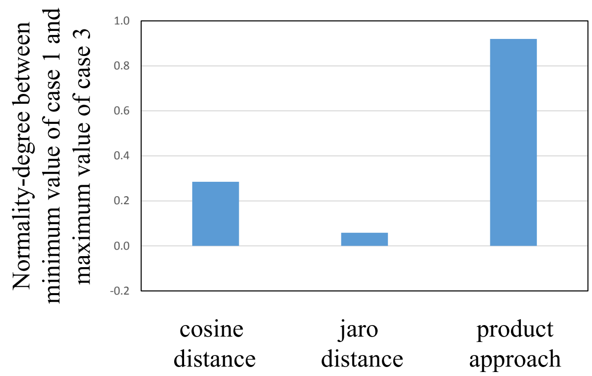

Figure 5. Normality-degree between minimum value of case 1 and maximum value of case 3

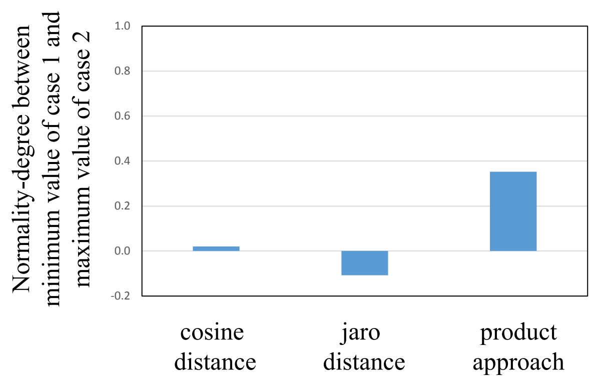

Figure 6. Normality-degree between minimum value of case 1 and maximum value of case 2

probability density (normal distribution) as shown in Fig. 4. The addition and deletion scores (D_1 and D_2) have an identical shape, as described in Section III-B. Their shapes are sharp, which implies that almost all the workflows have the same number of common log messages. On the other hand, the displacement score (D_3) has a blunt shape, which implies that the patterns of displacement vary.

Table V shows the maximum and minimum normality-degree, computed by the product approach. The results were calculated from the probability density (normal distribution) and normalized between 0 and 1. In the case of the product approach (proposed method), (2), (3) and (4) were used and derived three normal distributions as shown in Fig. 4. Compared with Tables III and IV, we found that the value of use cases 2 and 3 becomes lower due to the application of normal distribution.

Fig. 5 shows the normality-degree between the minimum value of use case 1 and the maximum value of use case 3. Fig. 6 shows the normality-degree between the minimum

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value of use case 1 and the maximum value of use case 2. This normality-degree indicates the distinguishability of the two use cases. Generally, use case 1 shows higher similarity than the other use cases. Therefore, the difference between the minimum value of use case 1 and the maximum value of other use cases is an important criterion for distinguishing among the use cases.

The results for the conventional and product approaches are clearly different. The product approach gives a higher normality-degree than the conventional approach does. This effectively works to distinguish between the normal and overload samples of the indeterminable workflows. In the conventional case, it is difficult to distinguish between the normal and overload samples. However, in the product approach, the normality-degrees have over a 0.3 difference between the normal and overload samples.

Although this evaluation only included the normal completions of the reference workflows, the semi-normal and abnormal completions show similar results to this normal completion case. We conjecture that this is because the proposed method takes into account the product of the addition, deletion and displacement. The product emphasizes low similarities, and makes clear the differences in the normality-degrees. This allows the system administrator to easily distinguish the indeterminable workflows that need troubleshooting.

V. CONCLUSION

This paper proposed a verification method for job execution in Openstack. The proposed method estimates the normality-degrees which are referred to in order to detect indeterminable workflows among many workflows (workflow with the least abnormal degree should be first).

The proposed method has two benefits: one is a way to divide log messages accumulated through multiple job executions into individual workflows with NMF; and the other is a way to estimate the normality-degree. The latter uses string similarity evaluation as a reference. We disassemble the string addition, deletion and displacement scores, and define the normality-degree by multiplying them.

We also revealed that the workflows in Openstack had similar but, strictly speaking, various patterns, and the proposed normality-degree has the ability to clearly distinguish the workflows.

The following issues remain as future work: evaluation of semi-normal and abnormal completions of the reference workflows, and clarifying the degree to which our approach (troubleshooting according to the normality-degree) brings stability to virtualized communication systems.

REFERENCES

[1] B. Pfaff, J. Pettit, T. Koponen, K. Amidon, M. Casado, and S. Shenker, “Extending networking into the virtualization layer,” in Proc. of work shop on Hot Topics in Networks (HotNets-VIII), 2009.

[2] ETSI GS NFV 002: Network Functions Virtualisation (NFV); Architectural Framework. [Online]. Available from: http://www.etsi.org/deliver/etsi_gs/NFV/001_099/002/01.02.01_60/gs_NFV002v010201p.pdf 2017.06.10

[3] B. Vazirnezhad, F. Almasganj, and S. M. Ahadi, “Hybrid statistical pronunciation models designed to be trained by a medium-size corpus,” Computer Speech and Language 23, pp. 1-24, 2009

[4] Openstack. [Online]. Available from: https://www.openstack.org/ 2017.06.10

[5] AT&T. [Online]. Available from: https://www.openstack.org/videos/video/at-and-ts-cloud-journey-with-openstack 2017.06.10

[6] Deutsche Telekom AG. [Online]. Available from: https://www.telekom.com/en/media/media-information/enterprise-solutions/telekom-strengthens-the-openstack-community-with-the-open-telekom-cloud-363316 2017.06.10

[7] Rackspace Cloud. [Online]. Available from: https://www.rackspace.com/cloud/private 2017.06.10

[8] B. C. Tak,S. Tao, L. Yang, C. Zhu, and Y. Ruan, “LOGAN: Problem Diagnosis in the Cloud Using Log-based Reference Models,” In Cloud Engineering (IC2E), pp. 62-67, 2016

[9] P. Zhou,B. Gill,W. Belluomini, and A. Wildani, “GAUL: Gestalt analysis of unstructured logs for diagnosing recurring problems in large enterprise storage systems,” In Reliable Distributed Systems, pp. 148-159, 2010

[10] C. B. Jiang,I. Liu, Y. N. Chung, and J. S. Li, “Novel intrusion prediction mechanism based on honeypot log similarity,” International Journal of Network Management, 2016

[11] Open Virtual Switch. [Online]. Available from: http://openvswitch.org/ 2017/06/10

[12] Q. Fu, J.-G. Lou, Y. Wang, and J. Li, “Execution anomaly detection in distributed systems through unstructured log analysis,” In Proceedings of the 2009 Ninth IEEE International Conference on Data Mining, ICDM ’09, pp. 149–158, 2009.

[13] K. Kc and X. Gu. Elt, “Efficient log-based troubleshooting systemfor computing infrastructures. In Reliable Distributed Systems(SRDS),” IEEE Symposium, pp. 11–20, 2011.

[14] D. D. Lee and H. S. Seung, “Learning the parts of objects with nonnegative matrix factorization”, Nature, 401, pp.788–791, 1999.

[15] D. D. Lee and H. S. Seung, “Algorithms for non-negative matrixfactorization,” Advances in Neural Information Processing Systems 13, MIT Press, pp. 556–562, 2001.

[16] T. Kimura, K. Takeshita, T. Toyono, M. Yokota, K. Nishimatsu, and T. Mori, “Network Failure Detection and Diagnosis by Analyzing Syslog and SNS Data: Applying Big Data Analysis to Network Operations,” NTT Technical Review, Nov 2013, Vol. 11, No. 11

[17] W. E. Winkler, "String Comparator Metrics and Enhanced Decision Rules in the Fellegi-Sunter Model of Record Linkage," Proceedings of the Section on Survey Research Methods. American Statistical Association, pp.354–359, 1990.

[18] Opentack Mitaka. [Online]. Available from: https://www.openstack.org/software/mitaka/ 2017/06/10

Multipath TCP Packet Scheduling for Streaming Video

Ryota Matsufuji, Dirceu Cavendish, Kazumi Kumazoe, Daiki Nobayashi, Takeshi Ikenaga
Department of Computer Science and Electronics
Kyushu Institute of Technology
Fukuoka, Japan
e-mail: {q349428r@mail, cavendish@ndrc, kuma@ndrc, nova@ecs, ike@ecs}.kyutech.ac.jp

***Abstract*—Video streaming has become the major source of Internet traffic nowadays. Considering that content delivery network providers have adopted Video over Hypertext Transfer Protocol/Transmission Control Protocol (HTTP/TCP) as the preferred protocol stack for video streaming, understanding TCP performance in transporting video streams has become paramount. Recently, multipath transport protocols have allowed video streaming over multiple paths to become a reality. In this paper, we propose packet scheduling disciplines for injecting video stream packets into multiple paths at the video server. We study video streaming performance when subjected to these schedulers in conjunction with current TCP variants. We utilize network performance measures, as well as video quality metrics, to characterize the performance and interaction between network and application layers of video streams for various network scenarios.**

Keywords*—*Video streaming; high speed networks; TCP congestion control; Multipath TCP; Packet retransmissions; Packet loss.

I. Introduction

Transmission control protocol (TCP) is the dominant transport protocol of the Internet, providing reliable data transmission for the large majority of applications. For data applications, the perceived quality of service is the total transport time of a given file. For real time (streaming) applications, the perceived quality of experience involves not only the total transport time, but also the amount of data discarded at the client due to excessive transport delays, as well as rendering stalls due to the lack of timely data. Transport delays and data starvation depend on how TCP handles flow control and packet retransmissions. Therefore, video streaming user experience depends heavily on TCP performance.

TCP protocol interacts with video application in non trivial ways. Widely used video codecs, such as H-264, use compression algorithms that result in variable bit rates along the playout time. In addition, TCP has to cope with variable network bandwidth along the transmission path. Network bandwidth variability is particularly wide over paths with wireless access links of today, where multiple transmission modes are used to maintain steady packet error rate under varying interference conditions. As the video playout rate and network bandwidth are independent, it is the task of the transport protocol to provide a timely delivery of video data so as to support a smooth playout experience.

Recently, multipath transport has allowed video streamed over multiple IP interfaces and network paths. Multipath streaming not only augments aggregated bandwidth, but also increases reliability at the transport level session even when a specific radio link coverage gets compromised. An important issue in multipath transport is the path (sub-flow) selection; a packet scheduler is needed to split traffic to be injected on a packet by packet basis. For video streaming applications, head of line blocking may cause incomplete or late frames to be discarded at the receiver, as well as stream stalling. In this work, we propose a couple of path schedulers and evaluate video streaming performance under these schedulers. To the best of our knowledge, there has not been a study of path selection mechanisms' performance of multipath video streaming in the literature.

The material is organized as follows. Related work discussion is provided on Section II. Section III describes video streaming over TCP system. Section IV introduces the TCP variants addressed in this paper, as well as Multipath TCP and path schedulers used to support multipath transport. Section V addresses multiple path video delivery performance evaluation for each TCP variant. Section VI addresses directions we are pursuing as follow up to this work.

II. Related Work

Although multipath transport studies are plenty in the literature, there has been few prior work on video performance over multiple paths [5] [11] [15]. In our previous work [10], Matsufuji et al. have evaluated multipath video streaming performance when widely deployed TCP variants are used in each path. Regarding multipath schedulers, there has been even less research activity. Yan et al. [16] propose a path selection mechanism based on estimated sub-flow capacity. Their evaluation is centered on throughput performance, as well as reducing packet retransmissions. Yan et al. [2] present a modelling of multipath transport in which they explain empirical evaluations of the impact of selecting a first subflow in throughput performance. Hwang et al. [8] propose a blocking scheme of a slow path when delay difference between paths is large, in order to improve data transport completion time on short lived flows. Finally, Ferlin et al. [6] introduces a path selection scheme based on a predictor of the head-of-line blocking of a given path. They carry out emulation experiments with their scheduler against the minimum rtt default scheduler, in transporting bulk data, Web transactions, and Constant Bit Rate (CBR) traffic, with figure of merits of goodput, completion time, and packet delays, respectively.

In contrast, our work seeks to propose and evaluate multipath path scheduling mechanisms and their impact on the quality of video streams. Previously [10], we have evaluated multipath video streaming using standard MPTCP path selection scheduler. In this work, we evaluate two new path sched-

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uler proposals. For performance evaluation, we use widely deployed TCP variants on open source network experiments over WiFi access links. The use of widely deployed TCP variants is motivated by the fact that path selection is constrained by the availability and size of congestion window controlled by TCP variants on each path.

III. Video Streaming over TCP

Video streaming over HTTP/TCP involves an HTTP server, where video files are made available for streaming upon HTTP requests, and a video client, which places HTTP requests to the server over the Internet, for video streaming. Figure 1 illustrates video streaming components.

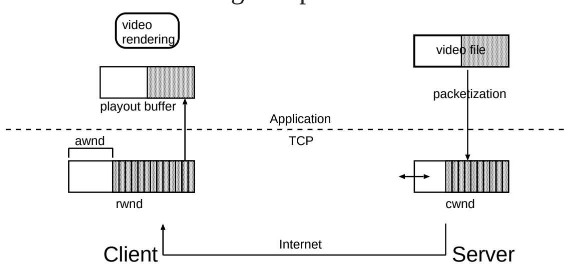

Figure 1: Video Streaming over TCP

An HTTP server stores encoded video files, available upon HTTP requests. Once a request is placed, a TCP sender is instantiated to transmit packetized data to the client machine. At TCP transport layer, a congestion window is used for flow controlling the amount of data injected into the network. The size of the congestion window, $cwnd$, is adjusted dynamically, according to the level of congestion in the network, as well as the space available for data storage, $awnd$, at the TCP client receiver buffer. Congestion window space is freed only when data packets are acknowledged by the receiver, so that lost packets are retransmitted by the TCP layer. At the client side, in addition to acknowledging arriving packets, TCP receiver sends back its current available space $awnd$, so that at the sender side, $cwnd \leq awnd$ at all times. At the client application layer, a video player extracts data from a playout buffer, filled with packets delivered by TCP receiver from its buffer. The playout buffer is used to smooth out variable data arrival rate.

A. Interaction between Video streaming and TCP

At the server side, HTTP server retrieves data into the TCP sender buffer according with $cwnd$ size. Hence, the injection rate of video data into the TCP buffer is different than the video variable encoding rate. In addition, TCP throughput performance is affected by the round trip time of the TCP session. This is a direct consequence of the congestion window mechanism of TCP, where only up to a $cwnd$ worth of bytes can be delivered without acknowledgements. Hence, for a fixed $cwnd$ size, from the sending of the first packet until the first acknowledgement arrives, a TCP session throughput is capped at $cwnd/rtt$. For each TCP congestion avoidance scheme, the size of the congestion window is computed by a specific algorithm at time of packet acknowledgement reception by the TCP source. However, for all schemes, the size of the congestion window is capped by the available TCP receiver space $awnd$ sent back from the TCP client.

At the client side, the video data is retrieved by the video player into a playout buffer, and delivered to the video renderer. Playout buffer may underflow, if TCP receiver window empties out. On the other hand, playout buffer overflow does not occur, since the player will not pull more data into the playout buffer than it can handle.

In summary, video data packets are injected into the network only if space is available at the TCP congestion window. Arriving packets at the client are stored at the TCP receiver buffer, and extracted by the video playout client at the video nominal playout rate.

IV. Anatomy of transmission control protocol

TCP protocols fall into two categories, delay and loss based. Advanced loss based TCP protocols use packet loss as primary congestion indication signal, performing window regulation as $cwnd_k = f(cwnd_{k-1})$, being ack reception paced. Most f functions follow an Additive Increase Multiplicative Decrease strategy, with various increase and decrease parameters. TCP NewReno [1] and Cubic [13] are examples of additive increase multiplicative decrease (AIMD) strategies. Delay based TCP protocols, on the other hand, use queue delay information as the congestion indication signal, increasing/decreasing the window if the delay is small/large, respectively. Compound [14], Capacity and Congestion Probing (CCP) [3] and Capacity Congestion Plus Derivative (CCPD) [4] are examples of delay based protocols.

Most TCP variants follow TCP Reno phase framework: slow start, congestion avoidance, fast retransmit, and fast recovery.

- **Slow Start(SS):** This is the initial phase of a TCP session. In this phase, for each acknowledgement received, two more packets are allowed into the network. Hence, congestion window $cwnd$ is roughly doubled at each round trip time. Notice that $cwnd$ size can only increase in this phase. So, there is no flow control of the traffic into the network. This phase ends when $cwnd$ size reaches a large value, dictated by $ssthresh$ parameter, or when the first packet loss is detected, whichever comes first. All widely used TCP variants use slow start except Cubic [13].
- **Congestion Avoidance(CA):** This phase is entered when the TCP sender detects a packet loss, or the $cwnd$ size reaches the target upper size $ssthresh$ (slow start threshold). The sender controls the $cwnd$ size to avoid path congestion. Each TCP variant has a different method of $cwnd$ size adjustment.
- **Fast Retransmit and fast recovery(FR):** The purpose of this phase is to freeze all $cwnd$ size adjustments in order to take care of retransmissions of lost packets.

For TCP variants widely used today, congestion avoidance phase is sharply different. We will be introducing specific TCP variants' congestion avoidance phase shortly.

A. Multipath TCP

Multipath TCP (MPTCP) is a transport layer protocol, currently being evaluated by IETF, which makes possible data transport over multiple TCP sessions [7]. The key idea is to make multipath transport transparent to upper layers, hence presenting a single TCP socket to applications. Under the hood, MPTCP works with TCP variants, which are unaware of the multipath nature of the overall transport session. To accomplish that, MPTCP supports a packet scheduler that extracts packets from the MPTCP socket exposed to applications, and injects them into TCP sockets belonging to a "sub-flow" defined by a single path TCP session. MPTCP transport architecture is represented in Figure 2.

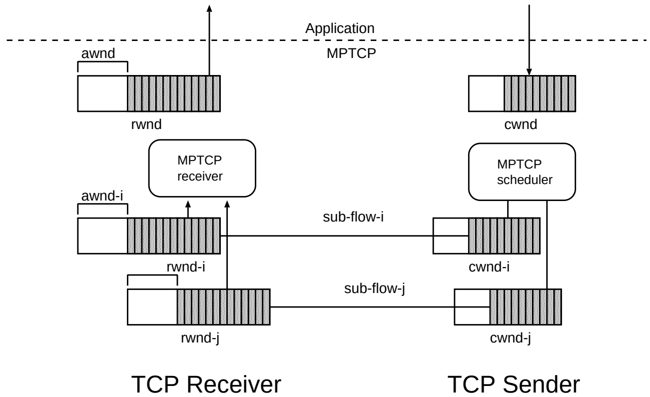

Figure 2: MPTCP Architecture

MPTCP packet scheduler works in two different configuration modes: uncoupled, and coupled. In uncoupled mode, each sub-flow congestion window $cwnd$ is adjusted independently. In coupled mode, MPTCP couples the congestion control of the sub-flows, by adjusting the congestion window $cwnd_k$ of a sub-flow k according with parameters of all sub-flows. Although there are several coupled mechanisms, we focus on Linked Increase Algorithm (LIA) [12] and Opportunistic Linked Increase Algorithm (OLIA) [9]. In both cases, a MPTCP scheduler selects a sub-flow for packet injection according to some criteria among all sub-flows with large enough $cwnd$ to allow packet injection.

Multipath Scheduling: MPTCP scheduler has the role of selecting which sub-flow to inject packets into the network. The default strategy is to select a path with shortest current packet delay. Here, we introduce two other path selection and packet injection mechanisms.

- **Shortest Packet Delay(SPD):** In shortest packet delay, the scheduler first rules out any path for which there is no space in its sub-flow congestion window (cwnd). Among the surviving paths, the scheduler then selects the path with small smooth round trip time (rtt). Smooth rtt is computed as an average rtt of recent packets transmitted at that sub-flow. Since each sub-flow already keeps track of its smooth rtt, this quantity is readily available at every sub-flow.
- **Largest packet credits(LPC):** Among the sub-flows with space in their cwnd, this scheduler selects the one with largest available space. Available space is the number of packets allowed by cwnd size minus the packets that have not been acknowledged yet.
- **Largest Estimated Throughput(LET):** In this case, among the sub-flows with large enough cwnd to accommodate new packets, the scheduler estimates the throughput of each sub-flow and selects the one with largest throughput.

The rationale for the proposed schedulers is as follows. LPC addresses the path scenario in which a large rtt path has plenty of bandwidth. In default scheduler, this path may be less preferred due to its large rtt, regardless of having plenty of bandwidth for the video stream. LET addresses the scenario of a short path with plenty of bandwidth. The default scheduler may select this path due to its short rtt. However, if the short rtt has a smaller cwnd, LET will divert traffic away from this path, whereas default scheduler will continue to inject traffic through it. In summary, a significant difference between these two proposed schedulers and the default scheduler is that path selection relies on path characteristics that are more dynamic (cwnd, in flight packet count) than packet delay (rtt).

B. Linked Increase Congestion Control

Link Increase Algorithm [12] couples the congestion control algorithms of different sub-flows by linking their congestion window increasing functions, while adopting the standard halving of $cwnd$ window when a packet loss is detected. More specifically, LIA cwnd adjustment scheme is as per (1):

$$AckRec : cwnd^i_{k+1} = cwnd^i_k + min(\frac{\alpha B_{ack} Mss^i}{\sum_0^n cwnd^p}, \frac{B_{ack} Mss^i}{cwnd^i})$$

$$PktLoss : cwnd^i_{k+1} = \frac{cwnd^i_k}{2} \quad (1)$$

where α is a parameter regulating the aggressiveness of the protocol, B_{ack} is the number of acknowledged bytes, Mss^i is the maximum segment size of sub-flow i, and n is the number of sub-flows. Equation (1) adopts $cwnd$ in bytes, rather than in packets (MSS), in contrast with TCP variants equations to be described shortly, because here we have the possibility of diverse MSSs on different sub-flows. However, the general idea is to increase $cwnd$ in increments that depend on $cwnd$ size of all sub-flows, for fairness, but no more than a single TCP Reno flow. The min operator in the increase adjustment guarantees that the increase is at most the same as if MPTCP was running on a single TCP Reno sub-flow. Therefore, in practical terms, each LIA sub-flow increases $cwnd$ at a slower pace than TCP Reno, still cutting $cwnd$ in half at each packet loss.

C. Opportunistic Linked Increase Congestion Control

Opportunistic Link Increase Algorithm [9] also couples the congestion control algorithms of different sub-flows, but with the increase based on the quality of paths. More specifically, OLIA cwnd adjustment scheme is as per (2):

$$AckRec : cwnd^i_{k+1} = cwnd^i_k + \frac{\frac{cwnd^i}{(rtt^i)^2}}{(\sum_0^n \frac{cwnd^p}{rtt^p})^2} + \frac{\alpha^i}{cwnd^i},$$

$$PktLoss : cwnd^i_{k+1} = \frac{cwnd^i_k}{2} \quad (2)$$

where α is a positive parameter for all paths. The general idea is to tune $cwnd$ to an optimal congestion balancing point (in the Pareto optimal sense). In practical terms, at each OLIA sub-flow increases $cwnd$ at a pace related to the ratio of its rtt and rtt of other subflows, still cutting $cwnd$ in half at each packet loss.

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D. Cubic TCP Congestion Avoidance

TCP Cubic is a loss based TCP that has achieved widespread usage as the default TCP of the Linux operating system. During congestion avoidance, its congestion window adjustment scheme is:

$$\begin{aligned} AckRec: \quad cwnd_{k+1} &= C(t-K)^3 + Wmax \\ K &= (Wmax\frac{\beta}{C})^{1/3} \\ PktLoss: \quad cwnd_{k+1} &= \beta cwnd_k \\ Wmax &= cwnd_k \end{aligned} \tag{3}$$

where C is a scaling factor, Wmax is the cwnd value at time of packet loss detection, and t is the elapsed time since the last packet loss detection (cwnd reduction). The rationale for these equations is simple. Cubic remembers the cwnd value at time of packet loss detection - Wmax, when a sharp cwnd reduction is enacted, tuned by parameter β. After that, cwnd is increased according to a cubic function, whose speed of increase is dictated by two factors: i) how long it has been since the previous packet loss detection, the longer the faster ramp up; ii) how large the cwnd size was at time of packet loss detection, the smaller the faster ramp up. The shape of Cubic cwnd dynamics is distinctive, clearly showing its cubic nature. Notice that upon random loss, Cubic strives to return cwnd to the value prior to loss detection quickly, for small cwnd sizes.

E. Compound TCP Congestion Avoidance

Compound TCP is the TCP of choice for most deployed Wintel machines. It implements a hybrid loss/delay based congestion avoidance scheme, by adding a delay congestion window dwnd to the congestion window of NewReno [14]. Compound TCP cwnd adjustment is as per (4):

$$\begin{aligned} AckRec: \quad cwnd_{k+1} &= cwnd_k + \frac{1}{cwnd_k + dwnd_k} \\ PktLoss: \quad cwnd_{k+1} &= cwnd_k + \frac{1}{cwnd_k} \end{aligned} \tag{4}$$

where the delay component is computed as:

$$\begin{aligned} AckRec: dwnd_{k+1} &= \begin{cases} dwnd_k + \alpha dwnd_k^K - 1, & \text{if } diff < \gamma \\ dwnd_k - \eta diff, & \text{if } diff \geq \gamma \end{cases} \\ PktLoss: dwnd_{k+1} &= dwnd_k(1-\beta) - \frac{cwnd_k}{2} \end{aligned} \tag{5}$$

where $diff$ is an estimated number of backlogged packets, γ is a threshold parameter which drives congestion detection sensitivity, and α, β, η and K are parameters chosen as a tradeoff between responsiveness, smoothness, and scalability.

Compound TCP dynamics is dominated by its loss based component, presenting a slow responsiveness to network available bandwidth variations, which may cause playout buffer underflows.

F. Capacity and Congestion Probing TCP

TCP CCP was our first proposal of a delay based congestion avoidance scheme based on solid control theoretical approach. The cwnd size is adjusted according to a proportional controller control law. The cwnd adjustment scheme is called at every acknowledgement reception, and may result in either window increase or decrease. In addition, packet loss does not trigger any special cwnd adjustment. CCP cwnd adjustment scheme is as per (6):

$$cwnd_k = \frac{[Kp(B - x_k) - in\_flight\_segs_k]}{2} \quad 0 \leq Kp \tag{6}$$

where Kp is a proportional gain, B is an estimated storage capacity of the TCP session path, or virtual buffer size, x_k is the level of occupancy of the virtual buffer, or estimated packet backlog, and in_flight_segs is the number of segments in flight (unacknowledged). Typically, CCP cwnd dynamics exhibit a dampened oscillation towards a given cwnd size, upon cross traffic activity. Notice that $cwnd_k$ does not depend on previous cwnd sizes, as with the other TCP variants. This fact guarantees a fast responsiveness to network bandwidth variations.

V. Video Streaming Performance of Multipath Schedulers

Figure 3 describes the network testbed used for emulating a network path with wireless access link. An HTTP video server is connected to two access switches, which are connected to a link emulator, used to adjust path delay and inject controlled random packet loss. A VLC client machine is connected to two Access Points, a 802.11a and 802.11g, on different bands (5GHz and 2.4GHz, respectively). All wired links are 1Gbps. No cross traffic is considered, as this would make it difficult to isolate the impact of TCP congestion avoidance schemes on video streaming performance. The simple topology and isolated traffic allows us to better understand the impact of differential delays on streaming performance.

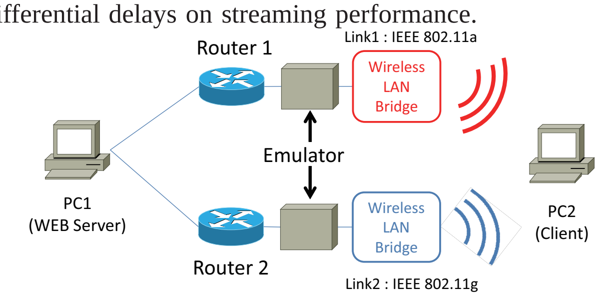

Figure 3: Video Streaming Emulation Network

TCP variants used are: Cubic, Compound, CCP, LIA and OLIA. Performance is evaluated for various round trip time path scenarios, as per Table I.

Table I: EXPERIMENTAL NETWORK SETTINGS

Element	Value
Video size	409Mbytes
Video rate	5.24Mbps
Playout time	10mins 24 secs
Encoding	MPEG-4
Video Codec	H.264 MPEG-4 AVC
Network Delay (RTT)	100, 200 msecs
TCP variants	Cubic, Compound, CCP, LIA, OLIA

The VLC client is attached to the network via a WiFi link. Iperf is used to measure the available wireless link bandwidth. UDP traffic injection experiments show that each wireless interface is limited to 5Mbps download speeds, which is lower than the video nominal playout rate of 5.24Mbps. Packet loss is hence induced only by the wireless link, and is reflected in the number of TCP packet retransmissions.

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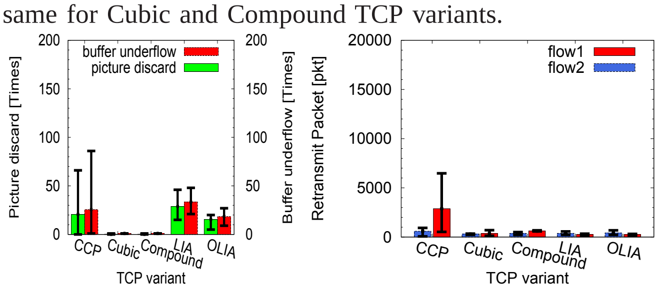
Performance measures adopted, in order of priority, are:

- **Picture discards:** number of frames discarded by the video decoder. This measure defines the number of frames skipped by the video rendered at the client side.
- **Buffer underflow:** number of buffer underflow events at video client buffer. This measure defines the number of "catch up" events, where the video freezes and then resumes at a faster rate until all late frames have been played out.
- **Packet retransmissions:** number of packets retransmitted by TCP. This is a measure of how efficient the TCP variant is in transporting the video stream data. It is likely to impact video quality in large round trip time path conditions, where a single retransmission doubles network latency of packet data from an application perspective.

We organize our video streaming experimental results into the following sub-sessions: i) Equal path delay; ii) Differential path delay. Each data point in charts represents five trials. Results are reported as average and min/max deviation bars.

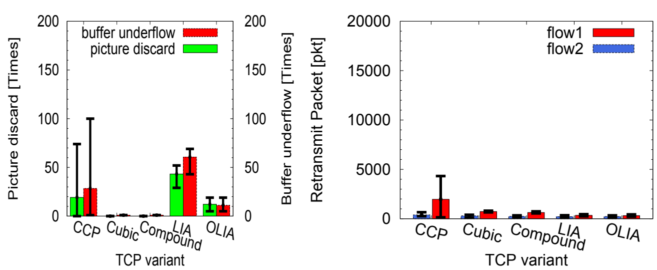
A. Equal Path Video Streaming Performance Evaluation

Figures 4, 5, and 6 report on video streaming throughput performance over equal paths delay of 100 msecs, for SPD, LPC, and LET schedulers, respectively. Notice first that under SPD, Cubic and Compound TCP variants deliver best video performance. In contrast, OLIA, CCP, and LIA deliver worse performance. When comparing SPD, LPC, and LET schedulers, video streaming performance under OLIA variants improves using LPC or LET schedulers, while it remains the same for Cubic and Compound TCP variants.



a) VLC performance b) TCP packets retransmitted

Figure 4: SPD Scheduler Streaming Perf.; rtts=100-100msecs

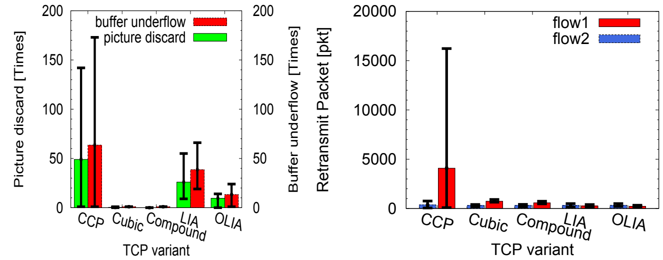


a) VLC performance b) TCP packets retransmitted

Figure 5: LPC Scheduler Streaming Perf.; rtts=100-100msecs

B. Differential Path Video Streaming Performance Evaluation

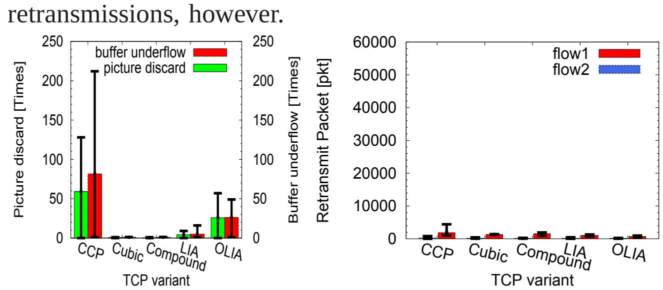
In these scenarios, default MPTCP scheduler tends to select the path with shorter delay, if $cwnd$ permits it. Only when TCP sender of the path with shorter delay happens to set its $cwnd$ to a very low value as compared with the longer path does MPTCP scheduler inject packets into the longer path.



a) VLC performance b) TCP packets retransmitted

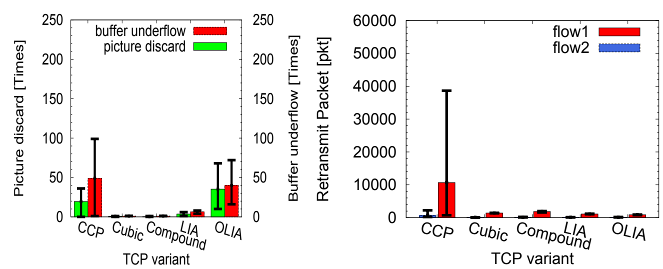
Figure 6: LET Scheduler Streaming Perf.; rtts=100-100msecs

Figures 7, 8, and 9 report on video streaming and TCP performance under two paths, the first path (802.11a) with a shorter 100msec delay, and the other (802.11g) with a longer 200msec delay, for SPD, LPC, and LET schedulers, respectively. Under default (SPD) scheduler, we continue to see better video performance under Cubic and Compound than CCP or coupled LIA and OLIA variants. When comparing schedulers, video streaming performance under CCP variant improves using LPC scheduler, it worsens for OLIA variant, and remains the same for Cubic and Compound TCP variants. CCP variant improvement comes at a cost of larger packet retransmissions, however.



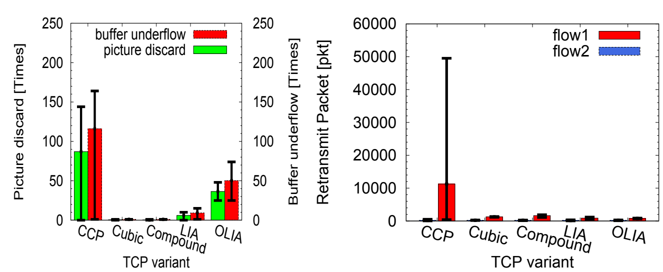
a) VLC performance b) TCP packets retransmitted

Figure 7: SPD Scheduler Streaming Perf.; rtts=100-200msecs



a) VLC performance b) TCP packets retransmitted

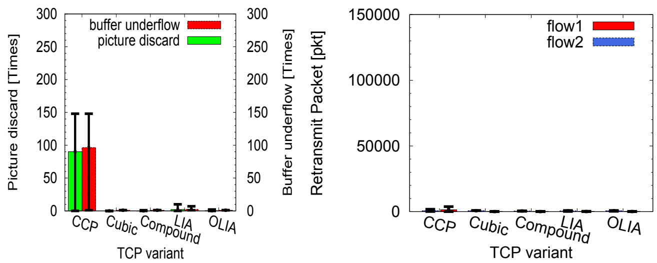
Figure 8: LPC Scheduler Streaming Perf.; rtts=100-200msecs



a) VLC performance b) TCP packets retransmitted

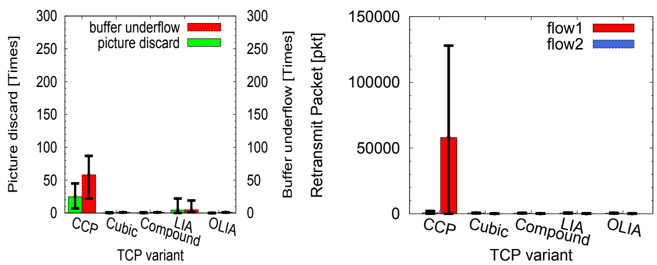
Figure 9: LET Scheduler Streaming Perf.; rtts=100-200msecs

Figures 10, 11, and 12 report on video streaming and TCP performance under two paths, the first path (802.11a) with a longer 200msec delay, and the other (802.11g) with a shorter 100msec delay, for SPD, LPC, and LET schedulers, respectively. Under default (SPD) scheduler, all TCP variants deliver similar video performance except CCP. When comparing path schedulers, video streaming performance under CCP variant improves using LPC scheduler, while it remains the same for the other TCP variants. Again, CCP video improvement comes at a cost of higher packet retransmissions.



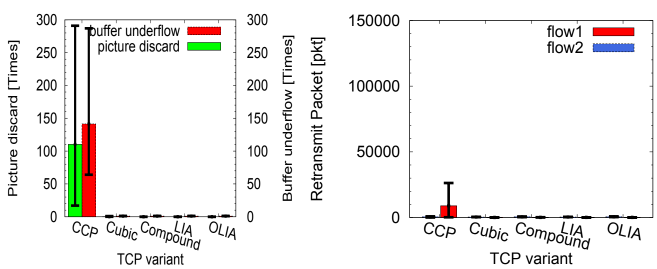
a) VLC performance b) TCP packets retransmitted

Figure 10: SPD Scheduler Streaming Perf.; rtts=200-100msecs



a) VLC performance b) TCP packets retransmitted

Figure 11: LPC Scheduler Streaming Perf.; rtts=200-100msecs



a) VLC performance b) TCP packets retransmitted

Figure 12: LET Scheduler Streaming Perf.; rtts=200-100msecs

In conclusion, Largest Packet Credit MPTCP scheduler improves video streaming performance of CCP variant overall, while having positive or no enhancement on the other TCP variants. We also detected that OLIA delivers better video experience than LIA coupled TCP variant across all path scenarios. We notice, however, that a two path transport scenario is constraining, in the sense that if one of the paths is blocked for transmission, for instance, due to some packet loss and small $cwnd$, all schedulers will select the other path, and hence will likely deliver the same performance. In our scenario, we traced a larger packet loss behavior of flow 2, which leads to different utilization of paths and performance if comparing 100-200msec delay scenario with 200-100msec delay scenario. Increasing the number of paths is a possibility, albeit such scenario may not be realistic in the near future.

VI. Conclusion and Future work

In this paper, we have proposed two new path schedulers and evaluated them on Multipath TCP transport of video streaming, using widely deployed TCP variants, as well as LIA and OLIA coupled TCP variants under consideration by IETF. We have characterized MPTCP performance with default and proposed path schedulers when transporting video streaming over two wireless network paths via open source experiments. Our experimental results show that injecting packets at the path with largest packet credits (cwnd - in flight packets) yields better video performance for OLIA coupled TCP variant and CCP. Cubic and Compound TCP variants deliver the same performance under all path schedulers studied. Hence, from a video performance viewpoint, either MPTCP in uncoupled mode or coupled with largest packet credit scheduler should be used. We are currently analyzing path schedulers' performance on more diverse multipath network scenarios.

Acknowledgments

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References

[1] M. Allman, V. Paxson, and W. Stevens, "TCP Congestion Control," IETF RFC 2581, April 1999.

[2] B. Arzani et al., "Deconstructing MPTCP Performance," In Proceedings of IEEE 22nd ICNP, pp. 269-274, 2014.

[3] D. Cavendish, K. Kumazoe, M. Tsuru, Y. Oie, and M. Gerla, "Capacity and Congestion Probing: TCP Congestion Avoidance via Path Capacity and Storage Estimation," IEEE Second International Conference on Evolving Internet, best paper award, pp. 42-48, September 2010.

[4] D. Cavendish, H. Kuwahara, K. Kumazoe, M. Tsuru, and Y. Oie, "TCP Congestion Avoidance using Proportional plus Derivative Control," IARIA Third International Conference on Evolving Internet, best paper award, pp. 20-25, June 2011.

[5] X. Corbillon, R. Aparicio-Pardo, N. Kuhn, G. Texier, and G. Simon, "Cross-Layer Scheduler for Video Streaming over MPTCP," ACM 7th International Conference on Multimedia Systems, May 10-13,2016, Article 7.

[6] S. Ferlin, et. al., "BLEST: Blocking Estimation-based MPTCP Scheduler for Heterogeneous Networks," In Proceedings of IFIP Networking Conference, pp. 431-439, 2016.

[7] A. Ford, et al., "Architectural Guidelines for Multipath TCP Development," IETF RFC 6182, 2011.

[8] J. Hwang and J. Yoo, "Packet Scheduling for Multipath TCP," IEEE 7th Int. Conference on Ubiquitous and Future Networks, pp.177-179, July 2015.

[9] R. Khalili, N. Gast, and J-Y Le Boudec, "MPTCP Is Not Pareto-Optimal: Performance Issues and a Possible Solution," IEEE/ACM Trans. on Networing, Vol. 21, No. 5, pp. 1651-1665, Aug. 2013.

[10] R. Matsufuji et al., "Performance Characterization of Streaming Video over Multipath TCP," IARIA 8th International Conference on Evolving Internet, pp. 42-47, November 2016.

[11] J-W. Park, R. P. Karrer, and J. Kim,, "TCP-Rome: A Transport-Layer Parallel Streaming Protocol for Real-Time Online Multimedia Environments," In Journal of Communications and Networks, Vol.13, No. 3, pp. 277-285, June 2011.

[12] C. Raiciu, M. Handly, and D. Wischik, "Coupled Congestion Control for Multipath Transport Protocols," IETF RFC 6356, 2011.

[13] I. Rhee, L. Xu, and S. Ha, "CUBIC for Fast Long-Distance Networks," Internet Draft, draft-rhee-tcpm-ctcp-02, August 2008.

[14] M. Sridharan, K. Tan, D. Bansal, and D. Thaler, "Compound TCP: A New Congestion Control for High-Speed and Long Distance Networks," Internet Draft, draft-sridharan-tcpm-ctcp-02, November 2008.

[15] J. Wu, C. Yuen, B. Cheng, M. Wang, and J. Chen, "Streaming High-Quality Mobile Video with Multipath TCP in Heterogeneous Wireless Networks," IEEE Transactions on Mobile Computing, Vol.15, Issue 9, pp. 2345-2361, 2016.

[16] F. Yan, P. Amer, and N. Ekiz, "A Scheduler for Multipath TCP," In Proceedings of IEEE 22nd ICCCN, pp. 1-7, 2013.

Trust on the Internet: How the French ccTLD .FR Went From a Remarkable to a Speculative System

Clement Genty, Henri Samier, Simon Richir
Arts et Métiers ParisTech, LAMPA,
Angers, France
email: clement.genty@ensam.eu

***Abstract*—The Domain Name System (DNS), was invented in 1983 because it was too hard for the human brain to memorize IP addresses. The DNS works as a phone directory, setting a link between letters, the domain name, and an IP address. Layered and structured since its creation, the domain name made it possible to identify the linked resource and to have confidence in its content. However, this classification system was quickly replaced a big bang of naming possibilities, where the first comer is the first and sole served. This survey aims to study the repercussing of the naming rules of the French ccTLD, the .FR. As an introduction and in section I, we will see how an area of trust has been created through the ".FR". Then, through the section III and IV, how the easing of registration and use rules initiated confusion over the identification and trust by the domain name. Finally, we propose three ways to create the identification-trust link.**

Domain Name System – Internet Trust – ccTLD – Internet Economics – Web Privacy – Semantic Web

I. INTRODUCTION

In 1984, J. Postel and J. Reynolds wrote the RFC920 [1], establishing the first domain names extensions. At the time, the idea was to read this sequence of alphanumeric characters from right to left, the extensions hierarchizing the domain names. COM, ORG, NET, EDU, MIL and ARPA became the first [2]. They will remain for posterity as generic constituents, called Generic Top Level Domain (gTLD).

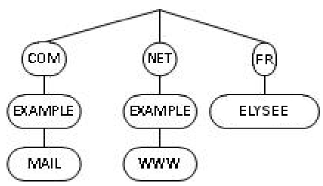

Figure 1. Architectures of domain names MAIL.EXAMPLE.COM, WWW.EXAMPLE.NET and NICE.FR

Two years later, Jon Postel created the first geographical Top Level Domain, grouped by countries and territories. This will be the ccTLD, Country-Code Top Level Domain. Using the ISO3166 postal standard [3], he picked the two-character country codes to create 243 extensions. This amount evolved after that, following the geopolitic situation. The fall of the Soviet Union and Yugoslavia has partially affected this list. Figure 1 gives an example of tree structure of the DNS.

II. FRENCH SITUATION

Regarding the .FR, a contact will be made between Postel and the INRIA, a French research institute speacialized in Computer Science and Automation, to delegate the French ccTLD.

Annie Renard and Jean-Yves Babonneau managed the .FR since September 2, 1986. Not being guided by any mimicry, the two researchers chose a hierarchical organization made of sub-domains and "le droit au nom", the entitlement to a domain name. Thus, the major part of professions, associations and governmental organizations will have their own private sub-domain name space. This structuring led them to contact the National Lawyer Union, representing the lawyer, the order of Geomatics Engineering Union, INPI, the French WIPO, etc. These rules of registration were listed in a naming charter where the "droit au nom" prevailed. Each entity had to respect the structure of the .FR ccTLD. Some users, however, preferred the use of a .COM domain name, less expensive and offering less restrictive registration conditions than the .FR, and unexposed to such administrative procedures.

Faced with these criticisms, the INRIA decided to take actions: in 1997, its value fell by 23% and in 1998 by 22%. This situation made the registration of .FR domain names cheaper than .COM.

To register a .FR domain name, the applicants had to be legal entities, to file a request by fax, which was individually checked before the registration. This administrative burden made the .FR domain name space less used, compared to European ones, less structured. The German ccTLD, .DE, allowed any registration since its delegation by Jon Postel, in November, 1986. Any applicants could have a domain name at the second level domain, i.e., directly in .DE.

Despite the administrative load that it generated, the French system of the .FR avoided the problem of cybersquatting, which was in the interest of domain names owners [4]. Indeed, the feeling of the trust in the .FR naming space was established. Similarly, numerous surveys highlighted the benefits of the French ccTLD.

Pressures, whether administrative or mercantile made the AFNIC, the newly formed association managing the .FR, to abandon the old registration rules: deletion of the "droit au nom" in 2004, opening to private individuals in 2006, deletion of most of the sub-domains in 2007 and

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allowance of one and two-characters domain names registration in 2014 [5].

The number of .FR domain names registrations became a Key Point Indicator for the AFNIC, as evidenced on its chief executive's resume [6].

The liberalization of the French ccTLD, .FR, had an important influence on the strategy of deposits. Once a flagship and application of French research, the .FR is managed by a semi-state associated structure that cannot act against the loss of confidence in domain names. If everybody can register anything, the legitimacy has given way to speculation.

The merchandising of computing resources, such as IP addresses [7] and now domain names, involves risks for the functioning of Internet [8].

Today, 3 million domain names are registered in .FR: 60% by organizations, 40% by individuals. While the deposits are supposed to be only opened to European citizens, Australia and China represent respectively the eleventh and fourteenth place of the countries of registration [9].

The number of registrations in .FR naming space is similar to the Italian's ccTLD. These figures, although apparently high, are considerably lower than those of Germany (.DE), 16 millions [10], and the Netherlands (.NL), 5.7 millions [11]. This situation has an important consequence on the identification-trust link, as shown in Figure 2.

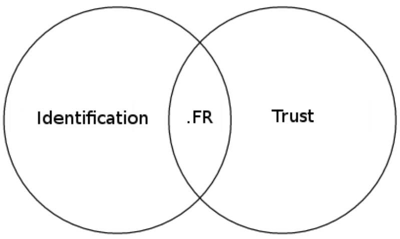

Figure 2. Identification-Trust link [12]

Originally, the French extension .FR had two goals:

- Identification: people are able to know the associated content by reading the domain name;
- Trust: registration rules exist before each deposit. People can trust the authority of the registrant;

III. IMPACT ON IDENTIFICATION

The absence of a naming charter defined for French administrative entities, apart from the .GOUV.FR sub-domain, prevents the identification function of the domain name. Under the former AFNIC charter, French embassies were supposed to be named under the form AMBA-YYY.FR, YYY being the name of the city or the country. Nowadays, embassies use the address AMBAFRANCE-XX.ORG, where XX is the ISO3166 country code.

- Of the 209 domain names beginning with "AMBAFRANCE", only 149 are official;
- Of the 150 official websites of the Embassies, only 138 comply with the AMBAFRANCE-XX.ORG charter;

The registration under .ORG being open to all, the preventive filing of domain names is thus necessary, as France has done for North Korea, where it does not have an embassy. AMBAFRANCE-KP.ORG was registered on December, 19. 2000 by the Ministry of Foreign Affairs.

In this case of French embassies, it is simply not possible to identify with certainty a website on the basis of its domain name. This situation exists since the liberalization of the French ccTLD .FR for commercial intent.

France overseas, represented by ISO3166 codes, is also impacted by the lack of numerical coherence.

- *Saint Pierre et Miquelon, Réunion, TAAF, Wallis-Futuna* and *Mayotte* inherit of an open naming charter similar to that of the .FR;
- *Guadeloupe, Martinique* and *French Guyana* have ccTLDs which are not managed by AFNIC despite the Postal and Telecommunications code provisions [13];
- *Saint-Barthelemy* (.BL) and *Saint-Martin* (.MF) have non-delegated extension, despite the stated will of *Saint-Barthelemy [14]*;
- *Clipperton* (.CP) has a non-delegated ccTLD;

NB: French Polynesia (.PF) and New Caledonia (.NC) are managed by other public bodies in agreement with the competent territorial authorities [15].

IV. IMPACT ON TRUST

An Internet address can both inspire implicit confidence and be a lure that can disturb consumer information. Let us take the recent case of addresses on the subject of abortion. The voluntary termination of pregnancy, commonly written and called IVG in France, has been authorized in the country since 1975. Many Internet websites, using the government's communication codes, act as official information websites. This situation is an issue given that 80% of young women aged 15-30 find the obtained information on the Internet credible. 57% get information on health issues via the Internet [16]. It is thus essential to give them a technical tool to identify reliable information on the Internet, as search engines do not include the veracity of the words in the search results. As we can see in Figure 3, subdomains work.

Conditions of the questionnaire: answer by form. 137 students with an average age of 18 years: 90 women, 47 men. 129 had their baccalaureate in 2016, 8 in 2015. 10 passed their C2I, a French IT and Internet certificate., 127 did not. One can thus define that it is a predominantly female population, being 18 years old and not being trained to the bases of the good understanding of the

Internet. Task: Rank these websites according to the confidence level: 0-1-2-3 (0 for the website you trust the less, 3 the more). Respondents are not allowed to click on the links, only identification by the domain name is possible.

Domain name	*Ranking*
IVG.SOCIAL-SANTE.GOUV.FR	2,27
IVG.FR	1,51
ECOUTEIVG.ORG	1,49
IVG.NET	1,07

Figure 3. Ranking

It can thus be noted that trust via the sub-domain ".GOUV.FR" is a reality. So-called "reserved" space, registration of domain names with this extension is only possible for the French Government. It is thus possible to develop and encourage the creation of spaces of trust.

Confronted with AFNIC's encouraging press releases on the ".FR's confidence", it can be noted that this extension has a classification similar to the extension .ORG considered "open", although enjoying an apparent image of confidence. .NET, considered as an alternative to .COM, occupies the last place.

V. Proposals

1. Creation of a French trust area

Faced with the difficulties generated by the liberalization of the .FR zone, which has become a commercial area, we now suggest using the .FX extension as a closed zone. The .FX extension, unused until now by France, originally represents metropolitan France. It is thus possible to use it as a hierarchical space with a right to the name for any holder of any right. Thus, through a logical hierarchy, it will be easy to define the legitimacy of depositors. Therefore, by creating and assigning namespaces for any user, France would become the first country to provide a domain name to its nationals:

- Free of a domain name and associated email address for any French entity or individual;
- Creation of a space of confidence, .FX, in addition to a commercial space, .FR;
- Strengthening of certain digital sovereignty in the face of confidentiality gaps (Yahoo, PRISM program, etc.);

As the .FX extension is part of the ISO 3166 code, France does not have to pay fees to the ICANN as it would be if the country intended to generate a new gTLD. This new space could be funded by delegating another unused extension, .CP (originally meant to stand for the Clipperton atoll) to an interested organization or company, just as Norway allowed the Netherlands to manage the extension .BV (corresponding to the Bouvet island, BV meaning *besloten vennootschap*, Ltd, in Dutch).

Formerly, the length of hierarchical domain names appeared as redhibitory, at a time when users often had to manually type domain names into their browsers. However, in 2017, the access to the major part of the information on the Internet is carried out through a search engine, the domain name being mainly used to identify the source. This will make it easier to index and archive.

As a conclusion, a major advertising campaign carried out by the APIE, could require depositors to use .FX instead of .FR. The rules of identification via the .FX space would be explained through the B2I and C2I, French IT and Internet Certificates [17].

2. Fighting speculation in the area.

In order to strengthen the .FR zone, it is suggested to propose the registration of domain names in .FR for a decennial period, similar to trademarks functionment, instead of annual fees. The financial curb would reduce the number of speculative registrations, motivated by an attractive rate. The fact of having to spend ten times as much, admittedly for ten times more temporal coverage, will generate a financial mechanism of restraint. The commitment contracted for every ten years, may be paid in annual installments.

A second step will be the regularization of domain name registrants, including the phasing out of domain names registered by non-European registrants. Alternatives, proposed by the registrars, exist, called local presences. The follow-up of the exit of Great Britain from the European Union will have to be carried out.

3. Delegation of overseas extensions

With a view to territorial homogeneity, it is advisable to encourage the French Government to have the extensions of Guadeloupe, Martinique and French Guyana delegated by AFNIC. Similarly, Saint-Barthelemy and Saint-Martin will have to be represented by a TLD subject to the possibility of registrations.

VI. Conclusion

These three proposals will serve to reinforce the French zones in the digital namespace. The proposed French system will be able to operate in the same way as the USA's system, which uses closed extensions (.GOV, .MIL, .EDU) and public (.COM, .BIZ, .US). It is essential today, in the face of the development of foreign solutions, to ensure digital sovereignty for France and its fellow citizens, through coherent and representative charters of qualifications and titles.

References

[1] J. Postel and J. Reynolds, "Domain Requirements", RFC920, October 1984

[2] J. Postel and J. Reynolds, ibid.

[3] ISO 3166 standard

[4] AFNIC, "Contrefaçon de marques et usurpation de noms de domaine, où en est la jurisprudence ?", February 2001, available on http://www.afnic.fr/data/actu/public/2001/conference-marques-noms-domaine-02-02-01.pdf [retrieved: June, 2017]

[5] AFNIC, "All about AFNIC Press kit", April 2015, available on www.afnic.fr/medias/documents/dossiers_de_presse/afnic-press-kit-2015-04.pdf [retrieved: June, 2017]

[6] AFNIC, “Mathieu Weill”, 2014, available on www.afnic.fr/medias/documents/resume-mathieu-weill-ceo-afnic.pdf [retrieved: June, 2017]

[7] P. Barbet, “Epuisement et marchandisation d’une ressource commune dans l’Internet: le cas des adresses IP”,Séminaire International Propriété et Communs, April 2013, available on www.mshparisnord.fr/ANR-PROPICE/25-26_avril/barbet_adresses-IP.pdf [retrieved: June, 2017]

[8] P. Barbet, “Les conséquences de la marchandisation croissante des ressources essentielles au fonctionnement du réseau Internet”, Revue internationale de droit économique, tXXVII, pp. 301-323, 2013

[9] AFNIC, “Open data AFNIC”, January 2017, available on opendata.afnic.fr/fr/produits-et-services/le-fr/opendata-fr.html [retrieved: June, 2017]

[10] DENIC, “DENIC eG: Wir sind .de”, January 2017, available on www.denic.de/ [retrieved: June, 2017]

[11] SIDN, “SIDN : Jouw wereld. Ons Domein”, January 2017, available on www.sidn.nl/

[12] C. Genty, H. Samier and ‘S. Richir’, “Noms de domaine et marques d'entreprise : de la disruption des politiques de nommage à celle des usages”, Colloque international de la Conception et Innovation (Confere; 23), Czech Republic, July 2016

[13] “Ordonnance n° 2014-329 du 12 mars 2014 relative à l'économie numérique“, March 2014, available on www.legifrance.gouv.fr/eli/ordonnance/2014/3/12/PMEX1402812R/jo/texte [retrieved: June, 2017]

[14] Collectivité de Saint-Barthélémy, “Délibération du Conseil territorial”, 2012-031CT, May 2012, available on www.comstbarth.fr/iso_album/2012-031_ct.pdf [retrieved: June, 2017]

[15] ITU, “Document pour l’atelier ccTLD, France”, March 2003, available on www.itu.int/itudoc/itu-t/workshop/cctld/cctld034-fr.pdf [retrieved: June, 2017]

[16] HCEfh, “ Rapport n°2013-0912-HCE-008 relatif à l’accès à l’IVG_Volet 1-Information sur l’avortement sur Internet”, 2013, available on www.haut-conseil-egalite.gouv.fr/IMG/pdf/hce-rapport_ivg_et_internet_20130912_version_adoptee-3.pdf [retrieved: June, 2017]

[17] Ministère de l’éducation nationale, de l’enseignement supérieur et de la recherche, “L’évaluation des compétences numériques”, available on www.education.gouv.fr/cid2553/le-brevet-informatique-et-internet-b2i.html [retrieved: June, 2017]

An Investigation of Tweets Submited by Using Music Player Applications

Yasuhiko Watanabe, Kenji Yasuda, Ryo Nishimura, and Yoshihiro Okada
Ryukoku University
Seta, Otsu, Shiga, Japan
Email: watanabe@rins.ryukoku.ac.jp, t130522@mail.ryukoku.ac.jp,
r_nishimura@afc.ryukoku.ac.jp, okada@rins.ryukoku.ac.jp

***Abstract*—What users are doing at a certain point in time is important for designing various services and applications in social media, such as targeted advertisement, news recommendation, and real-world analysis. As a result, in this study, we investigated tweets which users submitted when they were listening to music by using music player applications. We collected 2,000 tweets including hashtags generated by music player applications and found about 65% of them were tweets where impressions were described, 15 % of them were tweets where reasons why users were listening to music were described, and 10 % of them were tweets where actions while listening to music were described. We applied machine learning techniques to detect tweets where two kinds of actions while listening to music, moving to somewhere or going to bed, were described. The experimental result shows that our method is useful for providing behavior based services and applications in social media.**

Keywords–music player application; music content; behavior based service; Twitter; social media.

I. Introduction

Social media, such as Twitter and Facebook, generate large quantities of data about where users are and what they are thinking or doing at a certain point in time. Take tweets on Twitter, (exp 1) and (exp 2), for example. We can understand the submitters of these two tweets were listening to music. This is because #nowplaying in (exp 1) and (exp 2) show that these tweets were submitted by using music player applications. Users who are using music player applications are thought to be listening to music.

(exp 1) *#nowplaying: "soundscape" from "soundscape - Single" by TRUE (saisei kaisuu: 35) #songsinfo*
(#nowplaying: "soundscape" from "soundscape - Single" by TRUE (plays: 35) #songsinfo)

(exp 2) *#nowplaying kagerou by ONE OK ROCK on #onkyo #hfplayer*

#nowplaying is a hashtag generated by various music player applications [1]. Furthermore, #songsinfo in (exp 1) is a hashtag generated by a music player application, SongsInfo. Also, #onkyo and #hfplayer in (exp 2) are hashtags generated by a music player application, HF Player. These hashtags and the other words in (exp 1) and (exp 2) were all generated and embedded into these tweets automatically by music player applications when users submitted these tweets by using them. As a result, these hashtags enable us to understand that these users were listening to music when they submitted these tweets by using music player applications. As mentioned, (exp 1) and (exp 2) consist of words and hashtags all of which were generated by music player applications. On the other hand, (exp 3), (exp 4), and (exp 5) include words generated not only by music player applications but by users.

(exp 3) *#nowplaying: "Grow Slowly" from "Hafa Adai" by iguchi yuka (saisei kaisuu: 3) #songsinfo suki desu motto kiiteiru*
(#nowplaying: "Grow Slowly" from "Hafa Adai" by Iguchi Yuka (plays: 3) #songsinfo I like and listen to it so many times)

(exp 4) *basu wo nogashita node aruki masu !!#nowplaying: "walk on Believer ♪" from "walk on Believer ♪" by toyosaki aki (saisei kaisuu: 96) #songsinfo*
(I will walk because I missed the bus !! #nowplaying: "walk on Believer ♪" from "walk on Believer ♪" by toyosaki aki (plays: 96) #songsinfo)

(exp 5) *tenshon age te yakin ikuzo #nowplaying NIGHT FLIGHT by Perfume on #onkyo #hfplayer*
(I cheer myself up and go to night shift #nowplaying NIGHT FLIGHT by Perfume on #onkyo #hfplayer)

Specifically, the following words in (exp 3), (exp 4), and (exp 5) were generated not by music player applications but by users.

- *suki desu motto kiiteiru* (I like and listen to it so many times) in (exp 3),
- *basu wo nogashita node aruki masu !!* (I will walk because I missed the bus !!) in (exp 4), and
- *tenshon age te yakin ikuzo* (I cheer myself up and go to night shift) in (exp 5)

In this study, we describe user generated words in tweets submitted by using music player applications as *comments*. We will explain comments in tweets submitted by using music player applications in Section III. The comments in (exp 3), (exp 4), and (exp 5) express user's impression, action, and reason, respectively.

We can know that the submitters of (exp 3), (exp 4), and (exp 5) were listening to music when they submitted these tweets into Twitter. Furthermore, comments in these tweets enable us to understand what they were thinking and doing while listening to music. What users are thinking and doing at a certain point in time is important for designing various services and applications on social media, such as targeted advertisement, news recommendation, and real-world analysis. As a result, in this paper, we investigate tweets submitted by using music player applications and show what Twitter users are thinking and doing while listening to music. Furthermore, we discuss whether tweets submitted by using music player applications can be classified by using machine learning techniques.

The rest of this paper is organized as follows: In Section II, we survey related works. In Section III, we investigate tweets submitted by music player applications and show what the users are thinking and doing while listening to music. In Section IV, we apply machine learning techniques to classify tweets submitted by music player applications and discuss whether we can detect what the users are doing while listening to music. Finally, in Section V, we present our conclusions.

II. Related works

Twitter enables us to easily submit short messages in real time from anywhere with internet access. As a result, Twitter data is a valuable resource for predicting various trends and events. Taking this in consideration, there are many studies that have treated Twitter as a social sensor [2]. Aramaki et al. reported that Twitter messages reflect the real world and influenza related tweets can be extracted by using Twitter API and NLP techniques [3]. Also, Culotta showed that influenza-related Twitter messages can be identified by using a document classification method and a small number of flu-related keywords can forecast future influenza rates [4]. Sakaki et al. investigated the real-time nature of Twitter and proposed an event notification system that monitors tweets and delivers notification promptly [5]. Jansen et al. reported that microblogging is an online tool for customer word of mouth communications and potentially rich for companies to explore as part of their overall branding strategy [6].

Timestamps and geotags embedded into tweets are useful for treating Twitter as a social sensor. Some researchers conducted studies for event detection using geotags embedded into tweets. Lee and Sumiya proposed a method for detecting local events by applying a k-means clustering method to geotagged Twitter documents [7]. Kamath et al. studied the spatio-temporal dynamics of Twitter hashtags by using a sample of 2 billion geo-tagged tweets [8]. However, Watanabe et al. reported that less than one percent of Twitter posts are associated with a geolocation [9]. This is because Twitter users have been slow to adopt geospatial features and only a small amount of tweets comes with location information [10]. As a result, recent work has focused on geoinference for inferring the locations of posts. Yamaguchi et al. pointed out that most existing methods can be categorized into two kinds of approaches [11].

- a content-based approach or
- a graph-based approach

First, we discuss studies based on the content-based approach. The content-based approach leverages user-generated contents in the form of texts. Cheng at al. proposed a method for estimating a Twitter user's city-level location based purely on the content of the user's tweets [10]. Eisenstein et al. proposed a method of multi-level generative model that enables prediction of an author's geographic location from tweets [12]. Hecht et al. reported that user's home country and state can be reasonably inferred by using simple machine learning techniques [13]. Han et al. proposed a method of finding location indicative words via feature selection and examined whether the reduced feature set boosts geolocation accuracy [14]. Schulz et al. proposed a multi-indicator approach for determining the location where a tweet was created and the location of the user's residence [15]. Yamaguchi et al. proposed an online location inference method that can update inference results using only newly arriving contents without using previous contents [11].

Next, we discuss studies based on the graph-based approach. The graph-based approach is based on the structure of social graphs where friends are connected. This approach is based on an idea: users' social networks are useful for revealing their locations. For example, Twitter users are more likely to follow others that are geographically closer to them. As a result, Rout et al. described this approach as network-based approach [16]. Wang et al. used communication records of 6 million mobile phone subscribers and found that the similarity between individuals' movements, their social connectedness and the strength of interactions between them are strongly correlated with each other [17]. Backstrom et al. pointed out that, by using user-supplied address data and the network of associations between members of the Facebook social network, we can directly observe and measure the relationship between geography and friendship [18]. Rout et al. proposed an approach to geolocating users of online social networks, based solely on their friendship connections [16]. Sadilek et al. reported that we can infer people's fine-grained location, even when they keep their data private and we can only access the location of their friends [19].

Kinsella et al. pointed out that understanding where users are can enable a variety of services that allow us to present information, recommend businesses and services, and place advertisements that are relevant to where they are [20]. We also may say that understanding what users are thinking and doing can enable a variety of services that are relevant to what they are thinking and doing. However, few studies have been made on inferring what users are thinking and doing while many studies have been made on inferring where users are. As a result, in this paper, we investigate tweets submitted by using music player applications and show what Twitter users are thinking and doing while listening to music. Furthermore, we discuss whether tweets submitted by using music player applications can be classified by using machine learning techniques.

III. Investigation of tweets submitted by using music player applications

In this section, we investigate tweets submitted by music player applications and show what the users are thinking and doing while listening to music.

A. The investigation object

Tweets can be classified into three types [21]:

- reply
  A reply is submitted to a particular person. It contains "@username" in the body of the tweet. For example, (exp 6) is a reply to @eitaso.

  (exp 6) *@eitaso ore to nagoya de seigi no uta wo utawanaika ?* (^L^) *#nowplaying futten toppa ☆ LOVE IS POWER ☆ / chikyu bouei bu*
  (@eitaso Let's sing a song of justice in Nagoya? (^L^) #nowplaying futten toppa ☆ LOVE IS POWER ☆ / chikyu bouei bu)

- retweet
  A retweet is a reply to a tweet that includes the original tweet.

- normal tweet
  A normal tweet is neither reply nor retweet. For example, (ex 3), (ex 4), and (ex 5) are normal tweets. Normal tweets are generally submitted to general public.

In order to investigate tweets submitted by music player applications and what users are thinking and doing while listening to music, we collected the following 2000 tweets:

- 1,000 Japanese normal tweets including hashtag
  - #nowplaying
  - #songsinfo

  obtained from 13 October 2016 to 11 December 2016. These 1,000 tweets were submitted by 244 users.
- 1,000 Japanese normal tweets including hashtag
  - #nowplaying
  - #onkyo
  - #hfplayer

  obtained from 13 October 2016 to 1 December 2016. These 1,000 tweets were submitted by 345 users.

We did not collect the following tweets even if they include the hashtags above.

- replies,
- retweets, and
- tweets that include no comments generated by users.

As a result, (exp 1), (exp 2), and (exp 6) were not included in the collected 2000 tweets. Then, we extracted user generated comments from them by eliminating the following words.

- Uniform Resource Locators (URL),
- hashtags, and
- words generated automatically by music player applications.

As a result, we extracted *suki desu motto kiiteiru* (I like and listen to it so many times) from (exp 3) as an user generated comment. Also, we extracted *basu wo nogashita node aruki masu !!* (I will walk because I missed the bus !!) and *tenshon age te yakin ikuzo* (I cheer myself up and go to night shift) from (exp 4) and (exp 5), respectively.

B. Tweets which users submit when they use music player applications

We classified comments in tweets submitted by using music player applications into the following four types:

impressions — comments expressing users' impressions and evaluations of contents which they played by using music player applications,
reasons — comments expressing reasons why users played contents by using music player applications,
actions — comments expressing actions which users carried out when they used music player applications, and
others — comments that cannot be classified into the three types above.

Figure 1 shows the classification result of the obtained 2,000 Japanese tweets. These tweets were classified by human experts. We should notice that some comments can be classified into two types. For example, *yoi kyoku da!* (Good music!) in (exp 7) is classified into impressions. On the other hand, *ekurea katte kaero!* (Let's buy an eclair and go home!) is classified into actions.

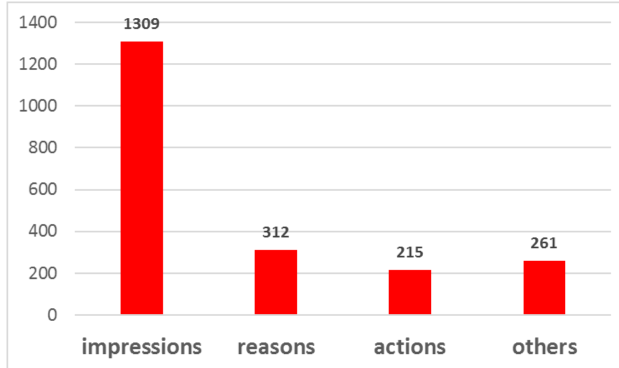

Figure 1. The classification result of the 2,000 tweets which users submit when they use music player applications (by human experts).

(exp 7) *yoi kyoku da! ekurea katte kaero!*
(Good music! Let's buy an eclair and go home!)

We shall discuss the following kinds of comments in detail.

- comments expressing impressions,
- comments expressing reasons, and
- comments expressing actions.

1) Comments expressing impressions: We found many comments expressing users' impressions and evaluations of contents which they played by using music player applications. Figure 1 shows that more than half of the obtained 2000 tweets were classified into ones expressing users' impressions, such as (exp 8) and (exp 9).

(exp 8) *yoi. suki.*
(Good. I like it.)
(exp 9) *natsukashi sugi te naki sou*
(I was close to tears)

In addition, we found that many comments expressing users' impressions were related to time, such as (exp 10) and (exp 11).

(exp 10) *kono jikantai ni kiku jazz ha, honto ni kimochi ga ii.*
(It's fun listening to jazz in this time period.)
(exp 11) *shinya no Neptunus ha kakubetsu.*
(It is wonderful to listen to Neptunus very late at night.)

Especially, most of them were related to time periods when users played music by using music player applications.

2) Comments expressing actions: For many years, psychology research has shown that people can attend to only one task at a time [22]. Hyman et al. reported that people talking on their cell phones while walking ran into people more often, and did not notice what was around them [23]. However, listening to music is an exception. We often do something while listening to music. Actually, we found many tweets where users described their actions while using music player applications. (exp 12), (exp 13), (exp 14), and (exp 15) are examples of comments expressing users' actions.

(exp 12) *tsuukin chu.. sawayakana hare.*

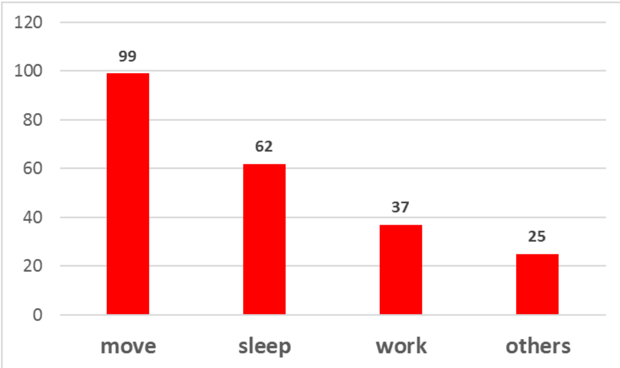

Figure 2. The classification result of the tweets expressing users' actions (by human experts).

(On my way to work.. It 's a crisp day.)

(exp 13) *oyasumi nasai*
(Good night)

(exp 14) *desaki deno gyomu shuryo. kiro he. yokohama live no set list.*
(I have finished my business out of the office. On my way home. The set list of the Yokohama live.)

(exp 15) *italo pop kiki nagara kare- shikomu yo*
(I will make curry with listening to Italo pop)

In our investigation, three kinds of most commonly actions described in tweets submitted by using music player applications are move, sleep, and work. For example, (exp 12) shows that the submitter was going to work with listening to music. (exp 13) shows that the submitter was going to sleep, and (exp 14) shows that the submitter had finished the job. As shown in Figure 1, we found 215 tweets expressing users' actions in the obtained 2,000 tweets which users submit when they use music player applications. We classified these 215 tweets expressing actions into four types:

- move
- sleep
- work
- others

Figure 2 shows the classification result of the tweets expressing users' actions. We found some tweets expressing users' actions can be classified into two types. For example, (exp 14) was classified into work and move. In particular, user's action expressed in *desaki deno gyomu shuryo* (I have finished my business out of the office) of (exp 14) was classified into work. On the other hand, user's action expressed in *kiro he* (On my way home) of (exp 14) was classified into move. Furthermore, some tweets expressing users' actions were classified into others. This is because they were classified into neither move, sleep, nor work. For example, (exp 15) was classified into others. As shown in Figure 2, many tweets expressing users' actions were classified into move and sleep. Hamamura and Iwamiya conducted the survey on the use of portable music player [24]. The survey was conducted on 72 college students, and 65 students and 39 students of them used portable music players while moving and working, respectively. This investigation result is in good agreement with ours. On the other hand, in their investigation result, there were no students who used portable music players while sleeping. The result is not in good agreement with ours. Furthermore, Hamamura and Iwamiya reported that 19 students used portable music players while shopping. On the other hand, we found only one comment, (exp 16), submitted by an user who were shopping while listening to music.

(exp 16) *osanpo & okaimono !*
(walk & shopping !)

3) Comments expressing reasons: We found many comments expressing users' reasons why they were listening to music by using music player applications.

(exp 17) *kibun teki ni kikitaku natta*
(I have a craving for music)

(exp 18) *katte shimatta*
(I finally bought it!)

(exp 17) and (exp 18) shows the reasons why the submitters of them were listening to music by using music player applications, feeling and acquisition, respectively. The submitter of (exp 17) felt an impulse and listened to music. On the other hand, the submitter of (exp 18) bought music contents and listened to it.

IV. Detection of Tweets Expressing Users' Actions

What users are doing at a certain point in time is important to design various services and applications in social media that are relevant to what they are doing. If we detect users' actions while listening to music automatically, we can design behavior based services and applications in social media more precisely. For example, users may have free time to use services and applications when they are listening to music and going to somewhere. On the other hand, users may not want to be disturbed when they are lying down on their beds and listening to music. As a result, in this section, we discuss whether we can detect tweets including hashtags generated by music player applications by using machine learning techniques.

In this study, we used the 2,000 tweets investigated in Section III for the experimental data. The experimental data include

- 99 comments expressing users' actions (move) and
- 62 comments expressing users' actions (sleep).

In this experiment, we used the support vector machine (SVM) and maximum entropy method (ME) for data training and classifying. Table I shows feature $s1 \sim s15$ used in machine learning on experimental data. $s1 \sim s7$ were obtained by using the results of morphological analysis on experimental data. In the experiments, we used a Japanese morphological analyzer, JUMAN, for word segmentation of tweets [25]. $s8 \sim s10$ and $s12 \sim s14$ were obtained by extracting character N-gram from experimental data. Odaka et al. reported that character 3-gram is good for Japanese processing [26]. $s4 \sim s7$ and $s12 \sim s15$ were obtained from first sentences of tweets. This is because, we thought, clue expressions of users' actions are often found at first sentences of tweets. We conducted this experiment using TinySVM [27] and maxent [28]. Table II and Table III show the SVM classification result of users' actions, move and sleep, in the 2,000 tweets, respectively. Also, Table IV and Table V show the ME classification result of users'

TABLE I. THE FEATURES USED IN MACHINE LEARNING METHODS FOR DATA TRAINING AND CLASSIFYING TWEETS EXPRESSING USERS' ACTIONS WHILE LISTENING TO MUSIC

$s1$	word unigrams of the comment
$s2$	word bigrams of the comment
$s3$	the number of words in the comment
$s4$	word unigrams of the first sentence of the comment
$s5$	word bigrams of the first sentence of the comment
$s6$	the number of words in the first sentence of the comment
$s7$	the last word of the first sentence of the comment
$s8$	character unigrams of the comment
$s9$	character bigrams of the comment
$s10$	character 3-grams of the comment
$s11$	the length of the comment
$s12$	character unigrams of the first sentence of the comment
$s13$	character bigrams of the first sentence of the comment
$s14$	character 3-grams of the first sentence of the comment
$s15$	the length of the first sentence of the comment

actions, move and sleep, in the 2,000 tweets, respectively. The experimental result was obtained with 10-fold cross-validation.

As shown in Table II and Table III, we obtained 97% and 99% accuracy when we applied SVM machine learning techniques to detect tweets including comments expressing user's move and sleep, respectively. Also, we obtained 97% and 99% accuracy when we applied ME machine learning techniques to detect tweets including comments expressing user's move and sleep, respectively. Furthermore, the SVM precision of tweets including comments expressing user's move and sleep were 91% and 100%, respectively. Also, the ME precision of tweets including comments expressing user's move and sleep were 95% and 100%, respectively. As a result, our method is useful to collecting tweets including comments expressing user's move and sleep, precisely. On the other hand, the SVM recall of tweets including comments expressing user's move and sleep were 48% and 79%, respectively. Also, the ME recall of tweets including comments expressing user's move and sleep were 41% and 73%, respectively. The reason why the recall of tweets including comments expressing user's sleep was better than that of move was that typical expressions, such as "*oyasuminasai* (good night)", were often used in comments expressing user's sleep than move. The experimental results show that our method is not enough to detect tweets expressing users' actions precisely. However, the precisions of our method show that tweets detected by our method are useful for understanding what users were doing. As a result, our method is useful for providing social media services, such as targeted advertisement, news recommendation, and real-world analysis.

V. CONCLUSION

Social media, such as Twitter, generate large quantities of data about what users are thinking and doing at a certain point in time. What users are thinking and doing at a certain point in time is important to design various services and applications in social media, such as targeted advertisement, news recommendation, and real-world analysis. As a result, in this study, we investigate tweets submitted by music player applications and show what users are thinking and doing while listening to music. Furthermore, we apply machine learning techniques

TABLE II. THE SVM CLASSIFICATION RESULT OF USERS' ACTIONS (MOVE) IN THE 2,000 TWEETS INCLUDING HASHTAGS GENERATED BY MUSIC PLAYER APPLICATIONS.

	SVM results		
users' actions	move	others	recall
move	48	51	0.48
others	5	1896	1.00
precision	0.91	0.97	

TABLE III. THE SVM CLASSIFICATION RESULT OF USERS' ACTIONS (SLEEP) IN THE 2,000 TWEETS INCLUDING HASHTAGS GENERATED BY MUSIC PLAYER APPLICATIONS.

	SVM results		
users' actions	sleep	others	recall
sleep	49	13	0.79
others	0	1938	1.00
precision	1.00	0.99	

TABLE IV. THE ME CLASSIFICATION RESULT OF USERS' ACTIONS (MOVE) IN THE 2,000 TWEETS INCLUDING HASHTAGS GENERATED BY MUSIC PLAYER APPLICATIONS.

	ME results		
users' actions	move	others	recall
move	41	58	0.41
others	2	1899	1.00
precision	0.95	0.97	

TABLE V. THE ME CLASSIFICATION RESULT OF USERS' ACTIONS (SLEEP) IN THE 2,000 TWEETS INCLUDING HASHTAGS GENERATED BY MUSIC PLAYER APPLICATIONS.

	ME results		
users' actions	sleep	others	recall
sleep	45	17	0.73
others	0	1938	1.00
precision	1.00	0.99	

to detect tweets submitted by music player applications and discuss whether we can detect tweets expressing what users are doing while listening to music. The experimental results show that our method is not enough to detect tweets expressing users' actions precisely. However, tweets detected by our method are useful for understanding what users were doing. As a result, our method is useful for providing social media services, such as targeted advertisement, news recommendation, and real-world analysis. We are now investigating the phases of users' actions, such as start, middle, and end. This is because the phases of users' actions enable us to provide more precise services and applications relevant to users' actions.

REFERENCES

[1] Twitter, "Using hashtags on twitter," https://support.twitter.com/articles/49309# [accessed: 2017-6-6].

[2] T. Sakaki and Y. Matsuo, "Twitter as a social sensor : Can social sensors exceed physical sensors?" Journal of Japanese Society for Artificial Intelligence, vol. 27, no. 1, jan 2012, pp. 67–74.

[3] E. Aramaki, S. Maskawa, and M. Morita, "Twitter catches the flu: Detecting influenza epidemics using twitter," in Proceedings

of the Conference on Empirical Methods in Natural Language Processing, ser. EMNLP '11. Stroudsburg, PA, USA: Association for Computational Linguistics, 2011, pp. 1568–1576. [Online]. Available: http://dl.acm.org/citation.cfm?id=2145432.2145600 [accessed: 2017-6-6]

[4] A. Culotta, "Towards detecting influenza epidemics by analyzing twitter messages," in Proceedings of the First Workshop on Social Media Analytics, ser. SOMA '10. New York, NY, USA: ACM, 2010, pp. 115–122. [Online]. Available: http://doi.acm.org/10.1145/1964858.1964874 [accessed: 2017-6-6]

[5] T. Sakaki, M. Okazaki, and Y. Matsuo, "Earthquake shakes twitter users: Real-time event detection by social sensors," in Proceedings of the 19th International Conference on World Wide Web, ser. WWW '10. New York, NY, USA: ACM, 2010, pp. 851–860. [Online]. Available: http://doi.acm.org/10.1145/1772690.1772777 [accessed: 2017-6-6]

[6] B. J. Jansen, M. Zhang, K. Sobel, and A. Chowdury, "Twitter power: Tweets as electronic word of mouth," J. Am. Soc. Inf. Sci. Technol., vol. 60, no. 11, Nov. 2009, pp. 2169–2188. [Online]. Available: http://dx.doi.org/10.1002/asi.v60:11 [accessed: 2017-6-6]

[7] R. Lee and K. Sumiya, "Measuring geographical regularities of crowd behaviors for twitter-based geo-social event detection," in Proceedings of the 2Nd ACM SIGSPATIAL International Workshop on Location Based Social Networks, ser. LBSN '10. New York, NY, USA: ACM, 2010, pp. 1–10. [Online]. Available: http://doi.acm.org/10.1145/1867699.1867701 [accessed: 2017-6-6]

[8] K. Y. Kamath, J. Caverlee, K. Lee, and Z. Cheng, "Spatio-temporal dynamics of online memes: A study of geo-tagged tweets," in Proceedings of the 22Nd International Conference on World Wide Web, ser. WWW '13. New York, NY, USA: ACM, 2013, pp. 667–678. [Online]. Available: http://doi.acm.org/10.1145/2488388.2488447 [accessed: 2017-6-6]

[9] K. Watanabe, M. Ochi, M. Okabe, and R. Onai, "Jasmine: A real-time local-event detection system based on geolocation information propagated to microblogs," in Proceedings of the 20th ACM International Conference on Information and Knowledge Management, ser. CIKM '11. New York, NY, USA: ACM, 2011, pp. 2541–2544. [Online]. Available: http://doi.acm.org/10.1145/2063576.2064014 [accessed: 2017-6-6]

[10] Z. Cheng, J. Caverlee, and K. Lee, "You are where you tweet: A content-based approach to geo-locating twitter users," in Proceedings of the 19th ACM International Conference on Information and Knowledge Management, ser. CIKM '10. New York, NY, USA: ACM, 2010, pp. 759–768. [Online]. Available: http://doi.acm.org/10.1145/1871437.1871535 [accessed: 2017-6-6]

[11] Y. Yamaguchi, T. Amagasa, H. Kitagawa, and Y. Ikawa, "Online user location inference exploiting spatiotemporal correlations in social streams," in Proceedings of the 23rd ACM International Conference on Conference on Information and Knowledge Management, ser. CIKM '14. New York, NY, USA: ACM, 2014, pp. 1139–1148. [Online]. Available: http://doi.acm.org/10.1145/2661829.2662039 [accessed: 2017-6-6]

[12] J. Eisenstein, B. O'Connor, N. A. Smith, and E. P. Xing, "A latent variable model for geographic lexical variation," in Proceedings of the 2010 Conference on Empirical Methods in Natural Language Processing, ser. EMNLP '10. Stroudsburg, PA, USA: Association for Computational Linguistics, 2010, pp. 1277–1287. [Online]. Available: http://dl.acm.org/citation.cfm?id=1870658.1870782 [accessed: 2017-6-6]

[13] B. Hecht, L. Hong, B. Suh, and E. H. Chi, "Tweets from justin bieber's heart: The dynamics of the location field in user profiles," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ser. CHI '11. New York, NY, USA: ACM, 2011, pp. 237–246. [Online]. Available: http://doi.acm.org/10.1145/1978942.1978976 [accessed: 2017-6-6]

[14] B. Han, P. Cook, and T. Baldwin, "Geolocation prediction in social media data by finding location indicative words," in COLING 2012, 24th International Conference on Computational Linguistics, Proceedings of the Conference: Technical Papers, 8-15 December 2012, Mumbai, India, M. Kay and C. Boitet, Eds. Indian Institute of Technology Bombay, 2012, pp. 1045–1062. [Online]. Available: http://aclweb.org/anthology/C/C12/C12-1064.pdf [accessed: 2017-6-6]

[15] A. Schulz, A. Hadjakos, H. Paulheim, J. Nachtwey, and M. Mühlhäuser, "A multi-indicator approach for geolocalization of tweets." in ICWSM, E. Kiciman, N. B. Ellison, B. Hogan, P. Resnick, and I. Soboroff, Eds. The AAAI Press, 2013.

[16] D. Rout, K. Bontcheva, D. Preoţiuc-Pietro, and T. Cohn, "Where's @wally?: A classification approach to geolocating users based on their social ties," in Proceedings of the 24th ACM Conference on Hypertext and Social Media, ser. HT '13. New York, NY, USA: ACM, 2013, pp. 11–20. [Online]. Available: http://doi.acm.org/10.1145/2481492.2481494 [accessed: 2017-6-6]

[17] D. Wang, D. Pedreschi, C. Song, F. Giannotti, and A.-L. Barabasi, "Human mobility, social ties, and link prediction," in Proceedings of the 17th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining, ser. KDD '11. New York, NY, USA: ACM, 2011, pp. 1100–1108. [Online]. Available: http://doi.acm.org/10.1145/2020408.2020581 [accessed: 2017-6-6]

[18] L. Backstrom, E. Sun, and C. Marlow, "Find me if you can: Improving geographical prediction with social and spatial proximity," in Proceedings of the 19th International Conference on World Wide Web, ser. WWW '10. New York, NY, USA: ACM, 2010, pp. 61–70. [Online]. Available: http://doi.acm.org/10.1145/1772690.1772698 [accessed: 2017-6-6]

[19] A. Sadilek, H. Kautz, and J. P. Bigham, "Finding your friends and following them to where you are," in Proceedings of the Fifth ACM International Conference on Web Search and Data Mining, ser. WSDM '12. New York, NY, USA: ACM, 2012, pp. 723–732. [Online]. Available: http://doi.acm.org/10.1145/2124295.2124380 [accessed: 2017-6-6]

[20] S. Kinsella, V. Murdock, and N. O'Hare, ""i'm eating a sandwich in glasgow": Modeling locations with tweets," in Proceedings of the 3rd International Workshop on Search and Mining User-generated Contents, ser. SMUC '11. New York, NY, USA: ACM, 2011, pp. 61–68. [Online]. Available: http://doi.acm.org/10.1145/2065023.2065039 [accessed: 2017-6-6]

[21] Y. Watanabe, K. Nakajima, H. Morimoto, R. Nishimura, and Y. Okada, "An investigation of a factor that affects the usage of unsounded code strings at the end of japanese and english tweets," in Proceedings of the Seventh International Conference on Evolving Internet (INTERNET 2015), Oct 2015, pp. 50–55. [Online]. Available: https://www.thinkmind.org/index.php?view=article&articleid=internet_2015_2_40_40038 [accessed: 2017-6-6]

[22] S. Weinschenk, 100 Things Every Designer Needs to Know About People, 1st ed. Thousand Oaks, CA, USA: New Riders Publishing, 2011.

[23] I. E. Hyman, S. M. Boss, B. M. Wise, K. E. McKenzie, and J. M. Caggiano, "Did you see the unicycling clown? inattentional blindness while walking and talking on a cell phone," Applied Cognitive Psychology, vol. 24, no. 5, 2010, pp. 597–607. [Online]. Available: http://dx.doi.org/10.1002/acp.1638 [accessed: 2017-6-6]

[24] M. Hamamura and S. Iwamiya, "Survey on the use of portable audio devices by university students," The Journal of the Acoustical Society of Japan, vol. 69, no. 7, jul 2013, pp. 331–339.

[25] S. Kurohashi and D. Kawahara, JUMAN Manual version 5.1 (in Japanese). Kyoto University, 2005.

[26] T. Odaka et al., "A proposal on student report scoring system using n-gram text analysis method," The transactions of the Institute of Electronics, Information and Communication Engineers. D-I, vol. 86, no. 9, sep 2003, pp. 702–705. [Online]. Available: http://ci.nii.ac.jp/naid/110003171273/en/ [accessed: 2017-6-6]

[27] Taku Kudoh. TinySVM: Support Vector Machines. [Online]. Available: http://chasen.org/~taku/software/TinySVM/index.html [accessed: 2017-6-6]

[28] M. Utiyama, "Maximum entropy modeling packages," http://mastarpj.nict.go.jp/~mutiyama/software/maxent [accessed: 2010-7-27], 2008.

Traffic-Aware Medium Access Control Protocol for Wireless Body Area Networks

Sabin Bhandari, Kishor Singh, and Sangman Moh
Dept. of Computer Engineering
Chosun University
Gwangju, South Korea
E-mail: sabinbhd@gmail.com, ikishor_singh@yahoo.com, smmoh@chosun.ac.kr

***Abstract*—Wireless body area networks (WBANs) can significantly improve healthcare, diagnostic monitoring, and other medical services. However, existing standards, such as IEEE 802.11 and IEEE 802.15.4 cannot fulfill all the requirements of WBANs. Numerous medium access control (MAC) protocols have been studied, most of which are derived from the IEEE 802.15.4 superframe structure with some improvements. Nevertheless, the MAC protocols do support required quality of service (QoS) for various forms of traffic coexisting in a WBAN. This paper proposes a traffic-aware MAC (TA-MAC) protocol for WBANs that allocates time slots dynamically based on traffic priority. The performance study shows that the proposed TA-MAC outperforms IEEE 802.15.4 MAC and the conventional priority-based MAC in terms of throughput and energy efficiency.**

Keywords-Wireless body area network; medium access control; energy efficiency; quality of service; traffic priority; IEEE 802.15.4.

I. Introduction

A wireless body area network (WBAN) is a special-purpose sensor network that is designed to autonomously connect various medical sensors and appliances located inside and around the human body and is capable of long-term health monitoring remotely or within a hospital. The general organization of a WBAN is shown in Figure 1. A WBAN consists of biomedical sensor nodes used to monitor physiological signals, such as electromyography (EMG), electroencephalography (EEG), temperature, heart rate, and blood pressure [1]. Quality of service (QoS) is an important benchmark to achieve in WBANs. The key requirements in WBANs are small device size, low power consumption, negligible electromagnetic effects to the human body, short transmission delay, high reliability, and effective communication. WBANs have specific requirements and considerations that the IEEE 802.15.4 medium access control (MAC) protocol does not fully address [2].

MAC protocols play a vital role in prolonging the lifespan of a network by controlling the sources of energy waste such as packet collisions, overhearing, control packet overhead, and idle listening [3] [4]. The main approaches adopted for energy savings in MAC protocols for WBANs are lower-power listening (LPL), schedule contention, and time division multiple access (TDMA). In the LPL mechanism, nodes wake up for a short duration to check the activity in the channel without receiving data. Scheduled contention is a combination of scheduling process and contention-based mechanism to avoid the problem of scalability and collision.

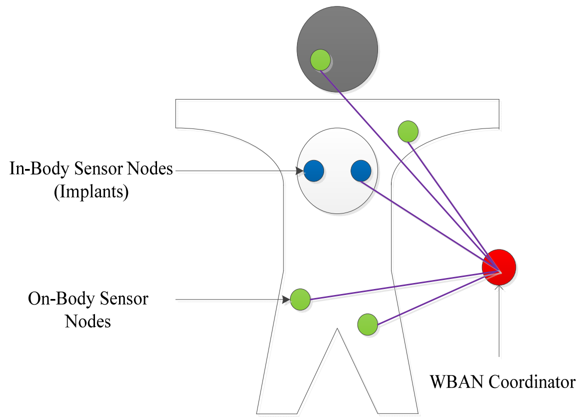

Figure 1. The general organization of a WBAN.

The IEEE 802.15.6 standard [5] defines new physical (PHY) and MAC layers to address both medical/healthcare applications and other nonmedical applications with diverse requirements. The MAC layer in the standard intends to define short-range wireless communication in and around the human body. The standard aims to support low complexity, low cost, ultra-low power, and highly reliable wireless communication for use in close proximity to or inside the human body (but not limited to the human body) to satisfy an evolutionary set of entertainment and healthcare products and services.

The design of MAC protocols has a significant impact on energy efficiency, interference, reliability, and QoS provision. One MAC protocol cannot satisfy the requirements of all applications because the protocols are hardware- and application-dependent [6]. The MAC protocol suitable for WBANs must handle specific challenges and issues associated with WBAN topology and node constraints. In [7], the different PHY and MAC layer design approaches to develop efficient mobile health (mHealth) applications for WBANs are surveyed and discussed. The key design features, MAC layer challenges, energy consumption, coexistence, and issues concerning channel modelling are analyzed and summarized in [8] [9].

In this paper, we propose a traffic-aware MAC (TA-MAC) protocol for WBANs that prioritizes the nodes by using a priority-guaranteed CSMA/CA procedure in the contention access period (CAP). For TA-MAC, we classify data traffic into four priorities and categorize the CAP into four sub-phases with dynamically changing length. This protocol is designed to support various QoS requirements for the data classified by priorities in WBANs. The proposed TA-MAC supports CAP and contention-free period (CFP). In the CAPs, the operation is based on a priority-guaranteed CSMA/CA procedure in which different WBAN nodes are assigned different priorities. The CFP is used to carry the large number of data packets to the coordinator.

This paper is organized as follows: In the following section, some related research is reviewed and discussed briefly. The proposed MAC protocol is presented in Section 3. In Section 4, the performance of the proposed TA-MAC is evaluated via computer simulation and compared with IEEE 802.15.4 MAC and the conventional priority-based MAC protocol. Section 5 concludes the paper.

II. Related Works

The IEEE 802.15.4 MAC protocol was designed for low-data-rate applications and is the most commonly used MAC protocol in wireless sensor networks to support low power and low data rate in cases where latency and bit rate are not critical [11]. The general characteristics of IEEE 802.15.4 MAC are low power consumption, support for low-latency devices, star or peer-to-peer operation, and dynamic device addressing. The superframe structure of IEEE 802.15.4 MAC consists of a CAP, a CFP, and an inactive period. The CFP contains up to seven guaranteed timeslots (GTS). The duration of the superframe is described by the values of macBeaconOrder (BO) and macSuperFrameOrder (SO). The BO describes the beacon interval at which the coordinator may transmit its beacon. IEEE 802.15.4 MAC does not have any mechanism for prioritizing among the different kinds of data traffic, and low-priority data can block the transmission of high-priority data.

There have been many significant developments of MAC protocols for WBANs. Most of the MAC protocols are already used for specific purposes, but they can be adopted with certain modifications to fulfill the requirements of WBANs. Most research has focused on the IEEE 802.15.4 standard for low-rate wireless personal area networks.

An IEEE 802.15.3-based MAC protocol was developed as part of a body area system for ubiquitous multimedia applications [12]. The main objective of a body MAC [13] is to achieve energy efficient and flexible operation in terms of bandwidth allocation and to support a sleep mode to fulfill the requirements of WBANs. The context-aware MAC protocol [14] was designed to guarantee the real-time transmission of life-critical and emergency data. In heartbeat-driven MAC (H-MAC) protocol [15], efficiency is achieved through the TDMA approach by reducing idle listening and avoiding collisions. In [16], support for multiple physical layers including ultra-wideband is taken into account. A multichannel management scheme for WBANs is introduced in [17]. In the traffic priority and load-adaptive MAC protocol presented in [18], the transmission schedules of packets are determined based on their priorities. The traffic-adaptive MAC (TaMAC) protocol [19] uses a traffic-based wakeup mechanism and a wakeup radio to accommodate normal, emergency, and on-demand traffic in a reliable manner. A traffic load-aware sensor MAC is reported in [20] for collaborative body area sensor networks. In [21], a traffic-aware dynamic MAC protocol (TAD-MAC) for both invasive and noninvasive WBANs is introduced. In [22], a novel priority-based channel access algorithm for contention-based MAC (NPCA-MAC) protocol is devised to solve the contention complexity problem. A hybrid and secure MAC (PMAC) protocol for WBANs [23] uses two CAPs for accommodating normal and critical data, whereas one CFP is used for accommodating the large amount of data packets. In low-delay traffic-adaptive MAC (LDTA- MAC) protocol [24], GTSs are allocated dynamically based on traffic load to improve some of the shortcomings of the IEEE 802.15.4 MAC.

Existing standards, such as IEEE 802.11 and IEEE 802.15.4 cannot fulfill all requirements of WBANs. Therefore, numerous MAC protocols have been studied. Most of them are derived from the IEEE 802.15.4 superframe structure with some improvements and adjustments. However, they do not support differentiated QoS for various kinds of traffic coexisting in a WBAN.

III. Traffic-aware MAC Protocol

In this section, the proposed TA-MAC is presented in detail. The priority level of different kinds of data traffic, dynamic timeslot allocation, and data transfer procedures are discussed in the following subsections.

A. *Priority Level of Traffic*

Among WBAN applications, medical and consumer electronics (CE) signals represent the majority of data traffic in the network. Emergency traffic, which is directly related to the life of a patient (e.g., emergency alarm signals) should be regarded as the most important service and must be in the first priority level. Continuous medical traffic with common vital signals (e.g., EEG, electromyography) ranks in the second priority level. Discontinuous medical traffic (e.g., temperature, blood pressure) ranks in the third priority level. CE traffic (e.g., audio/videos transmitted in an event-driven manner) is ranked in the fourth priority level. The priority levels for different kinds of traffic are shown in Table I.

TABLE I. Different Levels of Traffic Priority

Traffic	Priority level	Traffic	Example
Emergency traffic (ET)	1	P_1	Emergency alarm signal
On-demand traffic (OT)	2	P_2	Continuous medical signal (e.g., EEG, EMG)
Normal traffic (NT)	3	P_3	Discontinuous medical signal (e.g., temperature, blood pressure)
Nonmedical traffic (NMT)	4	P_4	Audio/video/data

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B. Dynamic Timeslot Allocation

The IEEE 802.15.4 MAC protocol consists of CAPs and CFPs. In this paper, we focus on the channel access of CAP because the performance of a CAP significantly influences the collision probability and the final throughput. When numerous nodes are densely deployed in a narrow region, contention complexity is increased and leads to high energy consumption and high collision. Contention complexity is one of the requirements of WBANs that must be satisfied so that the necessary QoS and low power consumption can be best achieved. Here, we divide the CAP into sub-phases for each priority level of traffic; i.e., ET-CAP (Phase 1), ODT-CAP (Phase 2), NT-CAP (Phase 3), and NMT-CAP (Phase 4) as shown in Figure 2. Nodes that transmit P_1 traffic can access channels through all phases from 1 to 4. P_2 can access channels from Phases 2 to 4. Similarly, P_3 can access channels through Phases 3 and 4. The node that transmits P_4 can use only Phase 4 to access the channel. Phase 1 always occupies the first time slot of the CAP [25]. To avoid wasted timeslot utilization, the length of sub-phases L_2, L_3, and L_4 dynamically change and are calculated by the coordinator according to number of priority nodes on that sub-phase using (1), (2), and (3), respectively.

The length of Phase 1 in Figure 2 is fixed; it is one time slot long and always occupies the first time slot of the CAP. However, the lengths of the remaining phases are variable and represented as

$$L_2 = \frac{N_2(L-1)}{\sum_{i=2}^{4} N_i}, \quad (1)$$

$$L_3 = \frac{N_3(L-1)}{\sum_{i=2}^{4} N_i}, \quad (2)$$

and

$$L_4 = L - L_3 - L_2 - 1, \quad (3)$$

where N_i is the number of ith priority nodes and L is the length of CAP in the unit of timeslot.

C. Data Transfer Procedure

In the IEEE 802.15.4 MAC protocol, the CAP is suitable for the transfer of short data and command messages, and the CFP is designed for transferring continuous data. The coordinator continuously broadcasts beacons to all nodes, and active nodes receive the beacons. The nodes send a request to the coordinator for allocation of time slots in the CAP. According to the number of requests received, the coordinator also allocates TDMA slots in the CFP. To alleviate the collision of data traffic, a GTS scheduling criterion is defined. For P_1 and P_3, the data are transmitted immediately after successfully accessing the channel in the CAP. However, for P_2 and P_4, the nodes uniformly send GTS request command frames in the CAP to apply for GTS allocation. The data transfer procedures for different priorities of traffic are shown in Figures 3 and 4. In the CAP, TA-MAC employs the priority-based CSMA/CA procedure, which is based on the IEEE 802.15.6 standard. Each priority class has differentiated maximum/minimum contention windows and contention probability values to provide priority-based channel access to satisfy the QoS requirements of WBANs [5].

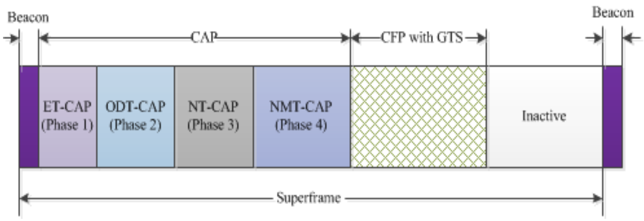

Figure 2. Superframe structure of the proposed MAC.

IV. PERFORMANCE EVALUATION

In this section, the performance of the proposed TA-MAC is evaluated via computer simulation and then compared to the existing IEEE 802.15.4 MAC and NPCA-MAC protocols.

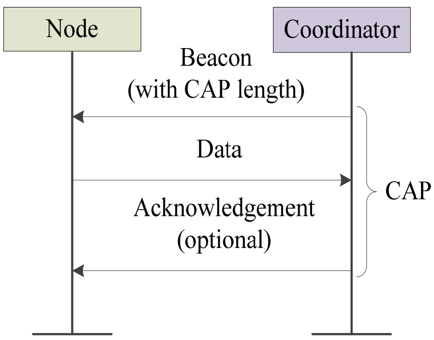

Figure 3. Data transfer for P_1 and P_3.

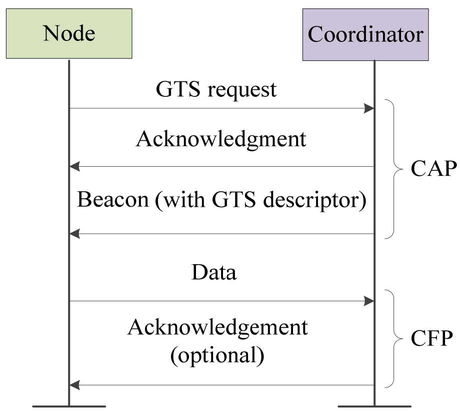

Figure 4. Data transfer for P_2 and P_4.

A. Performance Metrics

The performance metrics used in our simulation are throughput and energy efficiency. In this subsection, the metrics are summarized in brief. In addition, the effects of different priority levels are evaluated and discussed in terms of average transmission time.

Throughput in data communications refers to the actual level of traffic put through the network across a path between a transmitting device and one or more receiving devices, from end to end. It is defined as the average rate of successful packet delivery over a communication channel. Energy efficiency is one of the key requirements for WBAN MAC protocol designs.

Energy consumption depends on the behavior of the nodes on the network. A network with heavy traffic has higher energy consumption than one with low traffic activity. In order to comprehensively compare the MAC protocols, we calculated average energy consumption per bit to evaluate energy efficiency. The energy consumption per bit is defined as the total energy consumption over the total number of bits delivered during a simulation run [26].

B. Simulation Environment

Our performance simulation was carried out using the ns-2 network simulator version 2.35. In our simulation, it is assumed that several biomedical sensors are attached to or implanted into the human body. The sensors collect the sensed data and transmit them to the central coordinator, resulting in a star topology. All sensor nodes are randomly deployed within a 5 m radius around the central coordinator, and data are transmitted using one-hop communication [22]. The network parameters used for simulation are summarized in Table II as in [27].

TABLE II. SIMULATION PARAMETERS

Parameter	Value
Channel rate	250 kbps
Frequency band	2.4 GHz
Symbol times	16 µs
Superframe duration	122.88 ms
Transition time	194 µs
aUnitBackoffPriod	20 symbols
macBeaconOrder (BO)	3
macMaxCSMABackoffs	5
macMinBE	3
macMaxBE	5
Idle power	712 µW
Transmission power	36.5 mW
Reception power	41.4 mW

C. Simulation Results and Discussion

The overall throughput of the proposed TA-MAC, IEEE 802.15.4 MAC and NPCA-MAC is shown in Figure 5. The throughput is the total amount of data packets received by the coordinator in a specific time interval. Here, we can see that the throughput of all three protocols increases with the increase in the number of sensor nodes. When the network has low traffic load (i.e., less than 15 sensor nodes), all the three protocols perform similarly. With the increased number of sensor nodes, TA-MAC shows improved throughput over NPCA-MAC and IEEE 802.15.4 MAC. As a matter of fact, the classification of continuous and discontinuous data transfers and allocation of GTSs for continuous data makes TA-MAC outperform NPCA-MAC and IEEE 802.15.4 MAC.

The average energy consumption per bit as a function of the number of nodes is illustrated in Figure 6. The proposed TA-MAC and NPCA-MAC show better performance than IEEE 802.15.4 MAC in all network scenarios. However, TA-MAC shows slightly better performance than NPCA-MAC when the number of nodes is greater than 15. In general, packet collision and retransmission result in more energy consumption. As the number of nodes is increased, the energy consumption of IEEE 802.15.4 MAC is increased sharply because of high contention complexity. However, in the proposed TA-MAC, prioritized channel access with differentiated contention window, classification of data transfer, and backoff exponential values reduce the contention complexity, number of collisions, and packet retransmissions thus contributing to reduced energy consumption.

For comparing the performance of the sensor nodes according to their priority level, scenarios with the different number of sensor nodes per priority level are taken into evaluation. Figure 7 shows the effect of four different priority levels in terms of average transmission time for the different number of sensor nodes. In this paper, transmission

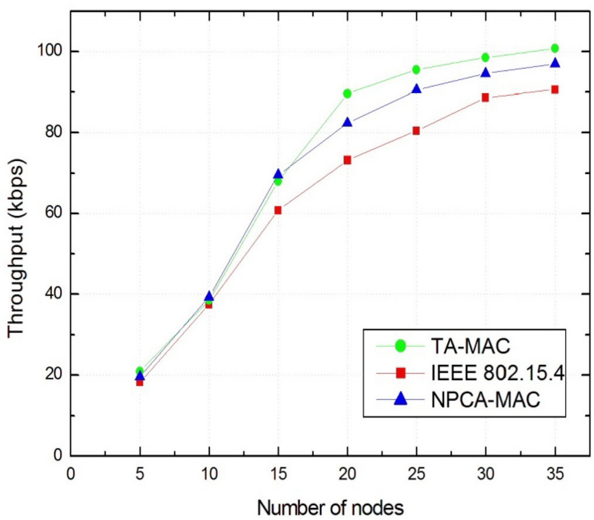

Figure 5. Network throughput.

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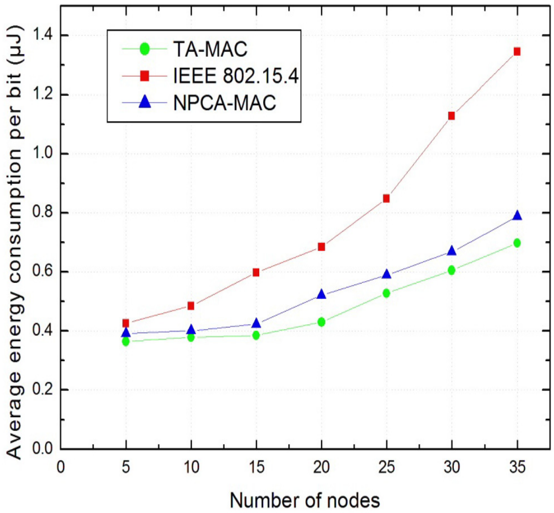

Figure 6. Average energy consumption per bit.

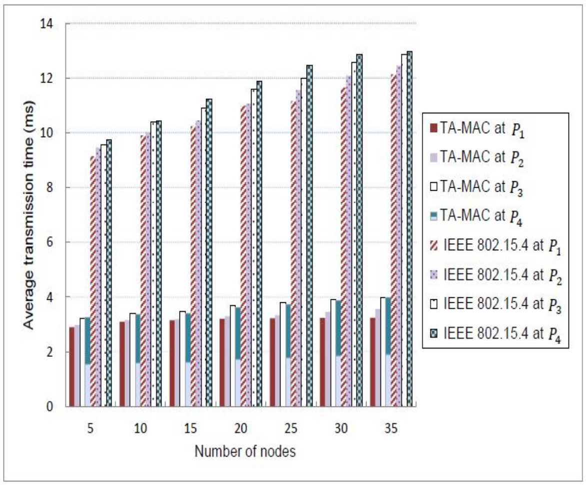

Figure 7. Effects of different priority level.

time is defined as the end-to-end delay from a sensor node to the coordinator. In Figure 7, the average transmission time of individual priority traffic is depicted for the proposed TA-MAC and IEEE 802.15.4 MAC, but the average transmission time of NPCA-MAC is not shown because it is almost the same as that of TA-MAC. This is primarily because NPCA-MAC also divides the CAP into four sub-phases according to the different priority levels of traffic as in TA-MAC. In NPCA-MAC, however, the continuous and discontinuous data transfer procedures and the use of GTSs were not considered. In addition, the number of sensor nodes per priority level is varied from 5 to 35 in Figure 7, and the impact on the average transmission time for the sensor nodes of each priority level is observed. As shown in Figure 7, the average transmission time tends to increase with the increase of priority level in both protocols. The difference is more noticeable in IEEE.15.4 in comparison to TA-MAC. It is obviously shown that TA-MAC shows better performance than IEEE 802.15.4 MAC.

V. Conclusions

In this paper, we have proposed a traffic-aware MAC protocol called TA-MAC for WBANs to support various QoS requirements. The proposed TA-MAC differentiates the access phase of the CAP and classifies the transfer procedure of priority-based traffic in WBANs. TA-MAC uses CFPs for continuous and large amounts of data. According to the simulation results, TA-MAC showed substantial improvements in terms of throughput and energy efficiency compared to IEEE 802.15.4 MAC and the conventional NPCA-MAC. A possible future work is to apply cognitive radio and multichannel access to the design of a MAC protocol for WBANs in order to mitigate the coexisting interference and improve network performance including QoS.

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References

[1] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith, and A. Jamalipour,"Wireless body area network: A survey," IEEE Communications Surveys and Tutorials, vol. 16, no. 3, pp. 1658-1686, 2014.

[2] IEEE Std. 802.15.4: Wireless medium access control (MAC) and physical layer (PHY) specifications for low data rate wireless personal area networks (WPAN), IEEE, Piscataway, NJ, USA, 2006.

[3] W. Ye, J. Heidemann, and D. Estrin, "An energy-efficient mac protocol for wireless sensor networks," Proc. of 21st Annual Joint Conference of the IEEE Computer and Communications Societies, vol. 16, pp. 1567-1576, June 2002.

[4] A. El-Hoiydi and J.-D. Decotignie, "WiseMAC: An ultra-low power mac protocol for the downlink of infrastructure wireless sensor networks," Proc. of 9th IEEE Symposium on Computers and Communication (ISCC'04), pp. 244-251, June- July 2004.

[5] S. Ullah, M. Chen, and K. Kwak, "Throughput and delay analysis of IEEE 802.15.6 based CSMA/CA protocol," Journal of Medical Systems, vol. 36, no. 6, pp. 3875-3891, 2012.

[6] S. Bhandari and S. Moh, "A survey of MAC Protocols for cognitive radio body area networks," Sensors, vol. 15, pp. 9189-9209, 2015.

[7] E. Kartsakli, A. Lalos, A. Antonopoulos, S. Tennina, M. Renzo, L. Alonso, and C. Verikoukis, "A survey on M2M systems for mHealth: A wireless communications perspective," Sensors, vol. 14, pp. 18009-18052, 2014.

[8] R. Cavallari, F. Martelli, R. Rosini, C. Buratti, and R. Verdone, "A survey on wireless body area networks:

Technologies and design challenges," IEEE Communications Surveys & Tutorials, vol. 16, pp. 1635-1657, 2014.

[9] T. Le and S. Moh, "Interference mitigation schemes for wireless body area sensor networks: A comparative survey," Sensors, vol. 15, pp. 13805-18838, 2015.

[10] S. Mangold, S. Choi, G. R. Hiertz, O. Klein, and B. Walke, "Analysis of IEEE 802.11e for QoS support in wireless LANs," IEEE Wireless Communications, vol. 10, No. 3, pp. 40-50, 2003.

[11] N. F. Timmons and W. G. Scanlon, "Analysis of the performance of IEEE 802.15.4 for medical sensor body area networking," Proc. of 1st Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks (IEEE SECON '04), pp. 16-24, Oct. 2004.

[12] T. Falck, J. Espina, J. P. Ebert, and D. Dietterle, "BASUMA – The sixth sense for chronically ill patients," Proc. of International Workshop on Wearable and Implantable Body Sensor Networks, Apr. 2006.

[13] G. Fang and E. Dutkiewicz, "BodyMAC: Energy efficient TDMA-based MAC protocol for Wireless Body Area Network," Proc. of 9th International Symposium on Communications and Information Technology, pp. 1455-1459, Sep. 2009.

[14] Z. Yan and B. Liu, "A context aware MAC protocol for medical wireless body area network," Proc. of 7th Int. Wireless Communication and Mobile Computing Conf. (IWCMC 2011), pp. 2133-2138, July 2011.

[15] L. Huaming and T. Jindong, "Heartbeat-driven medium-access control for body sensor networks," IEEE Transactions on Information Technology in Biomedicine, vol. 14, no. 1, pp. 44-51, 2010.

[16] C. Li, L. Wang, J. Li, B. Zhen, H.-B. Li, and R. Kohno, "Scalable and robust medium access control protocol in wireless body area networks," Proc. of IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications, pp. 2127-2131, Sept. 2009.

[17] W. Lee, S. H. Rhee, Y. Kim, and H. Lee, "An efficient multi-channel management protocol for wireless body area networks," Proc. of International Conference on Information Networking (ICOIN), pp.1-5, Jan. 2009.

[18] I. Anjum, N. Alam, M. A. Razzaque, M. Mehedi Hassan, and A. Alamri, "Traffic priority and load adaptive mac protocol for qos provisioning in body sensor networks," International Journal of Distributed Sensor Networks, vol. 2013, pp. 1-9, 2013.

[19] K. S. Kwak and S. Ullah, "A traffic-adaptive MAC protocol for WBAN," Proc. of IEEE GLOBECOM Workshops, pp. 1286-1289, Dec. 2010.

[20] O. Md. Rahman, C. S. Hong, S. Lee, and Y.-C. Bang, "ATLAS: A traffic load aware sensor MAC design for collaborative body area sensor networks," Sensors, vol. 11, no.12, pp. 11560-11580, 2011.

[21] M. M. Alam, O. Berder, D. Menard, and O. Sentieys, "TAD-MAC: traffic-aware dynamic mac protocol for wireless body area sensor networks," IEEE Journal on Emerging and Selected Topics in Circuits and Systems, vol. 2, no.1, pp. 109-119, 2012.

[22] B. Kim and J. Cho, "A novel priority-based channel access algorithm for contention-based MAC protocol in WBANs," Proc. of the 6th International Conference on Ubiquitous Information Management and Communication (ICUIMC 2012), pp. 1-5, Feb. 2012.

[23] S. Ullah, M. Imran, and M. Alnuem, "A hybrid and secure priority-guaranteed MAC protocol for wireless body area network," International Journal of Distributed Sensor Networks, vol. 2014, pp. 1-7, 2014.

[24] C. Li, B. Hao, K. Zhang, Y. Liu, and J. Li, "A novel medium access control protocol with low delay and traffic adaptivity for wireless body area networks," Journal of Medical Systems, pp. 1265-1275, 2011.

[25] S. Jin, Z. Weixia, and Z. Zheng, "Priority-based adaptive timeslot allocation scheme for wireless body area network," in Proc. of 13th International Symposium on Communications and Information Technologies (ISCIT), pp. 609-614, Sept. 2013.

[26] Y. Zhang and G. Dolmans, "Priority-guaranteed MAC protocol for emerging wireless body area networks," Annals of Telecommunications, vol. 66, pp. 229-241, 2010.

[27] X. Liang and I. Balasingham, "Performance analysis of the IEEE 802.15.4 based ECG monitoring network," Proc. of the 7th IASTED International Conferences on Wireless and Optical Communications, pp. 99-104, May-June 2007.