Multicast Group Management for Users of Heterogeneous Wireless Networks

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***Abstract*—Today mobile devices are typically equipped with multiple access network interfaces. Another important issue is a coexistence of heterogeneous wireless access networks. The selection of optimal serving mobile networks for multicast streams is a challenging problem. We consider a network selection problem for multicast groups of mobile clients that operate in a heterogeneous wireless access network environment. We identify several decision makers solving this problem and present our view on what kind of information is needed to be exchanged between these decision markers.**

***Index Terms*—Wireless networking, mobile network selection, decentralized algorithms.**

I. Introduction

The increasing market of mobile devices and mobile services, as well as availability of various wireless network technologies challenge resource limitations of wireless access networks. According to Cisco [1], global mobile data traffic grew 2.3-fold in 2011, more than doubling for the fourth year in a row. It confirms the previous Cisco forecasts from 2010 and 2011 and it is expected that mobile data traffic will double again in 2012. Mobile video traffic, the quality of which is particularly sensitive to network conditions, was 52% of the total traffic by the end of 2011. The number of mobile-connected tablets tripled to 34 million in 2011, and each tablet generated 3.4 times more traffic than the average smartphone. It is expected that mobile-connected tablets will generate almost as much traffic in 2016 as the entire global mobile network in 2012. In 2016, 4G will be 6 percent of connections covering 36 percent of total traffic. Monthly global mobile data traffic will surpass 10 exabytes in 2016. This growth poses extra challenges both on mobile network resources and on resources of the backhaul infrastructure that connects a mobile network to the backbone Internet. This requires rethinking of how the data is delivered to the users.

Multicast is an efficient method for point-to-multipoint communications and reduces drastically the usage of network resources when the same content is sent to a large group of users. Different types of applications like video conferencing, file distribution, live multimedia streaming can benefit from deploying multicast networking. However, the well-known complexity of managing multicast makes the deployment of multicast even more challenging in wireless environments when mobility issues have to be considered. In this paper, we consider a solution for network selection problem for heterogeneous mobile networking as a part of multicast group management.

The remainder of the paper is organized as follows. After presenting an overview of related work in Section II, we discuss a representative scenario in Section III. We present the problem formulation and outline a suitable algorithm in Section IV, before concluding and discussing future work in Section V.

II. Related Work

To the best of our knowledge, the research field concerning selection of a network in heterogeneous wireless networks from a perspective of multicast delivery is not well exploited. Most of the previous works for mobile multicast focus on optimal multicast tree construction in multihop ad hoc networks [2–5].

Ormond and Murphy [6] propose a network selection approach that uses a number of possible utility functions. The solution is user-centric and an interplay between different users and networks is not considered; neither is a multicast scenario. Ormond and Murphy conclude that the impact of multiple users operating in the same region need to be further examined.

Gluhak et al. [7] consider the problem of selecting the optimal bearer paths for multicast services with groups of heterogeneous receivers. The proposed algorithm selects the bearer path based on different optimization goals. However, Gluhak et al. address the problem only for the ideal static multicast case without taking into account users crossing different cells. In their work, multicast membership does not change during the duration of a service, and multicast groups are not built with consideration of users' movements. In our opinion, this is not a realistic case for wireless networks.

Yang and Chen [8] propose a bandwidth-efficient multicast algorithm for heterogeneous wireless networks that is formulated as an Integer Linear Programming problem that is solved using Lagrangian relaxation. The algorithm deals only with constructing optimal shortest path trees for multicast groups. In this approach, important parameters such as cost of service, user's velocity, etc. are not considered.

Jang et al. [9] present a mechanism for efficient network resource usage in a mobile multicast scenario. This mechanism is developed for heterogeneous networks and implements network selection based on network and terminal characteristics and QoS. However, in the proposed mechanism, the network

 ISBN: 978-1-61208-220-2

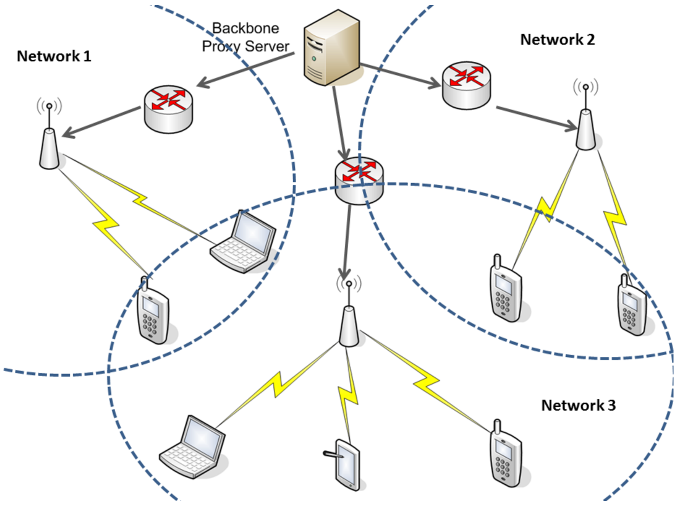

Figure 1. Multicast streaming scenario for a group of mobile clients served by several mobile networks before regrouping.

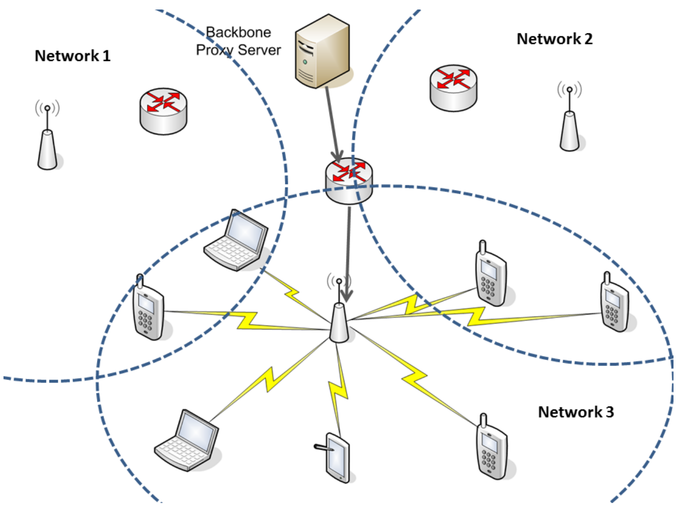

Figure 2. Multicast streaming scenario for a group of mobile clients served by several mobile networks after regrouping.

selection is performed purely based on terminal's preferences, the network perspective is not considered, and the solution does not optimize the utilization of network resources.

In our analysis, we recognize that the authors have not addressed several important aspects related to the network selection for mobile multicast groups. We need to study how the users' movements influence the optimality of building multicast groups and how the information needed for network selection is exchanged between the decision makers. We think that it is also important to consider how the signaling infrastructure is built.

III. SCENARIO

To illustrate the yet unsolved challenges for optimal network selection in multicast networks, we consider a multimedia streaming scenario for a group of mobile users that concurrently receive the same content from the Internet. We assume that a backbone proxy server (BPS) is placed at the network edge. The BPS is a member of a content distribution system (CDN). This scenario is an extension of a scenario that we previously have considered to illustrate an adaptive multimedia streaming architecture to mobile nodes [10].

The BPS streams the content that either is hosted on the server, or resends the streaming content as a part of application layer multicast. The users of this network are located in an area with a substantial overlap in coverage of several mobile networks, and are connected to different networks. The base stations of the system have multicast capabilities, implementing, for example, Multimedia Broadcast Multicast Service [11]. A representative scenario of such networking is illustrated in Figure 1.

In our scenario, the mobile terminals are capable to connect to several access networks, and vertical handoffs between these networks are technically possible. Further, we assume that these terminals are equipped with GPS receivers, so that their location information can be transmitted to the BPS. The BPS can use this information to determine how the users can be regrouped in multicast groups. Such regrouping is beneficial as it saves network resources. Hence, the users that get the same content can exploit the same wireless link because the content can be broadcasted to them. The resources in the backhaul network are also better utilized because the content is now delivered only to one mobile network instead of being spread to several networks. An example of such regrouping is depicted in Figure 2.

Technically, to facilitate such a mechanism, the user terminals will have the possibility to switch to other mobile networks after receiving certain messages from the BPS. Since users may have different preferences depending on diverse criteria, for example, power consumption, security, network cost of service, etc., the interplay between the users' utilities and the networks' utilities is important to consider.

IV. PROBLEM FORMULATION

In this section, we formalize the scenario discussed in Section III.

A. System Model

We consider a set of networks $N = 1, 2, \ldots, n$, a set of mobile nodes $M = 1, 2, \ldots, m$ and a set of streaming sessions $S = 1, 2, \ldots, s$. Each session s_k is served to more than one mobile node m_j. Therefore, using multicast for data dissemination is beneficial. For each node m_j and network n_i, the following is defined: streaming bitrate requirements of mobile nodes are denoted by r_j; $rss_{i,j}$ is the received signal strength in network n_i for terminal m_j, while power consumption and the cost of service in network n_i for node m_j are denoted by $p_{i,j}$ and $c_{i,j}$, respectively. Location information for node m_j is denoted by l_j For each node m_j, we define a user preference profile that is described by a tuple containing $Th^p_{i,j}$, $Th^c_{i,j}$, and $Th^{rss}_{i,j}$. These denote thresholds or user preferences, for, respectively, power consumption, cost of service and received signal strength. We define a time period

 ISBN: 978-1-61208-220-2

At Backbone Proxy Server
for each ongoing streaming session s_k
define set of mobile networks M_k receiving s_k
for each mobile node m_j receiving streaming session s_k
using node's GPS information l_j :
define set of available networks for m_j as a subset of M_k
send message to mobile node m_j requesting:
node's preferences for each available network n_i
for each network n_i from list of available networks
send message containing request about mobile node's $\tau_{i,j}$
wait for response from mobile node m_j
wait for response from requested networks
upon reception of response from nodes and networks
partition mobile nodes in multicast groups
for each multicast group
for each mobile node m_j in multicast group
send *invite* message to join multicast group

(a) Backbone Proxy Server View

At Mobile Network n_i
upon reception of request from Backbone Proxy Server
define $\tau_{i,j}$ for mobile node m_j
send $\tau_{i,j}$ to Backbone Proxy Server

(b) Mobile Network View

At Mobile Node m_j
upon reception of request from Backbone Proxy Server
for each mobile network in request define *preferences*
send set of *preferences* to Backbone Proxy Server
wait for response from Backbone Proxy Server
upon reception *invite* message from Backbone Proxy Server
switch to new mobile network

(c) Mobile Node View

Figure 3. Algorithm for Building Mobile Multicast Groups

$\tau_{i,j}$ during which node m_j is served by network n_i before performing a handoff and moving to the next cell of this network. Here, we assume that a mobile network is capable to predict the residence time of a mobile node inside a cell of the network based on mobile node velocity, the local area, movement patterns, and other statistical information. We base our decision making process on research done by other authors [12–14]. While the prediction of the residence time of mobile nodes is ongoing work, we consider this beyond our scope. For the purpose of this paper, we assume that the prediction can be performed with acceptable precision.

B. Algorithm

The system model defined in Section IV-A is used to construct the algorithm for network selection. The purpose of the algorithm in Figure 3 is to provide the information exchange between the clients, the networks, and the backbone proxy. The execution of this algorithm is triggered on the backbone proxy by detecting several streaming sessions from the same source to different mobile networks, as shown in Figure 3(a). The algorithm is capable of handling multisource situations, i.e., the same content can be received from multiple sources.

After the networks and mobile clients receive requests from the backbone proxy, the networks detect the residence time for requesting mobile clients as shown in Figure 3(b). The clients determine their preferences about the networks in question, as shown in Figure 3(c), and send these values to the BPS. These responses are then used by the BPS as an input for the partitioning algorithm.

The partitioning problem falls under the class of the integer programming problem and we consider several heuristic methods to implement the algorithm. We plan to evaluate approaches of using *Greedy*, *Vertex Substitution*, and *Neighborhood Search* methods [15]. These methods require a relatively low number of iterations (approx. 3000), which is important for real time systems.

C. Simulation Setup

We will implement these methods in the OMNet++ environment [16] and evaluate them through multiple simulation runs. We consider for the simulation a scenario with four, five and six wireless networks to be representative, assuming over 1000 mobile users in the system. The simulations will show in which way the algorithm is susceptible to the number of mobile users. Further, we divide the users into five categories in terms of requested content. The time $\tau_{i,j}$ for the user j to stay in the network n_i before performing a horizontal handoff, or a cell residence time, is randomly distributed in the range $[1, 100]$ time units. The users arrive in the system at a rate of about 10 users per second. In this experiment, we will evaluate the total consumed bandwidth for all networks and compare these results with the results of the algorithm proposed by Jang et al. [9].

D. Signaling

For signaling between the backbone proxy and mobile clients, we envisage to use RTCP [17] feedbacks, while session management will be handled using RTSP [18]. RTSP is also used for signaling between the backbone proxy and the mobile networks. RTCP is designed to exchange QoS feedback and synchronisation between media streams in the form of out-of-band statistics and control information for an RTP [18] flow. We intend also to evaluate whether using SIP [19] could have lower signaling overhead compared to RTSP/RTCP. However, while SIP is designed for call setup of media sessions, the exchange of QoS values can only be achieved using additional, non-standardized features. To encapsulate QoS values in SIP messages, we envisage to implement the SIP Multicast Mechanism defined by Yang and Chen [20].

V. Conclusion and Discussion

The paper studied the problem of selecting the optimal network for multicast groups of mobile clients in multi-stream scenario based on mobile clients' preferences and location information.

We define the information that needs to be exchanged between the decision makers and the mechanisms for disseminating the information. We intend to continue our work by implementing and evaluating this solution in the OMNet++ environment [16]. We also intend to compare the solution with the work proposed by Jang et al. [9] that was previously discussed in Section II.

In this paper, we considered one backbone proxy server that also operates as a central decision maker for initiating the network selection operation. However, it is highly probable that different edge servers can be used as proxies for different mobile access networks even if these networks overlap geographically. It is, therefore, important to define mechanisms that are capable of functioning in a decentralized way. Also, we need careful security considerations related to users' location information that becomes available to several entities of the system.

VI. Acknowledgment

The work described in this paper has been conducted as a part of the ADIMUS (Adaptive Internet Multimedia Streaming) project which is funded by the NORDUnet-3 programme.

References

[1] Cisco, "Cisco visual networking index: Global mobile data traffic forecast update, 2011-2016," 2012.

[2] M. Gerla, C.-C. Chiang, and L. Zhang, "Tree multicast strategies in mobile, multishop wireless networks," *Mob. Netw. Appl.*, vol. 4, no. 3, pp. 193–207, Oct. 1999.

[3] C.-C. Chiang, M. Gerla, and L. Zhang, "Forwarding group multicast protocol (FGMP) for multihop, mobile wireless networks," *Cluster Computing*, vol. 1, no. 2, pp. 187–196, Apr. 1998.

[4] J. G. Jetcheva, "Adaptive demand-driven multicast routing in multi-hop wireless ad hoc networks," Ph.D. dissertation, Carnegie Mellon University, Pittsburgh, PA, USA, 2004.

[5] J. Yuan, Z. Li, W. Yu, and B. Li, "A cross-layer optimization framework for multihop multicast in wireless mesh networks," *Selected Areas in Communications, IEEE Journal on*, vol. 24, no. 11, pp. 2092 –2103, nov. 2006.

[6] O. Ormond and J. Murphy, "Utility-based intelligent network selection," in *In Proceedings of the IEEE International Conference on Communications*, 2006.

[7] A. Gluhak, K. Chew, K. Moessner, and R. Tafazolli, "Multicast bearer selection in heterogeneous wireless networks," in *IEEE Int'l Conf. on Communications, ICC 2005*, vol. 2, may 2005, pp. 1372–1377.

[8] D.-N. Yang and M.-S. Chen, "Efficient resource allocation for wireless multicast," *IEEE Transactions on Mobile Computing*, vol. 7, no. 4, pp. 387–400, Apr. 2008.

[9] I.-S. Jang, W.-T. Kim, J.-M. Park, and Y.-J. Park, "Mobile multicast mechanism based mih for efficient network resource usage in heterogeneous networks," in *Proc. of the 12th Int'l Conf. on Advanced Communication Technology*, ser. ICACT'10, 2010, pp. 850–854.

[10] W. Leister, T. Sutinen, S. Boudko, I. Marsh, C. Griwodz, and P. Halvorsen, "An architecture for adaptive multimedia streaming to mobile nodes," in *MoMM '08: Proceedings of the 6th International Conference on Advances in Mobile Computing and Multimedia*. ACM, 2008, pp. 313–316.

[11] G. Xylomenos, V. Vogkas, and G. Thanos, "The multimedia broadcast/multicast service," *Wireless Communications and Mobile Computing*, vol. 8, no. 2, pp. 255–265, 2008.

[12] B. Liang and Z. J. Haas, "Predictive distance-based mobility management for multidimensional PCS networks," *IEEE/ACM Trans. Netw.*, vol. 11, no. 5, pp. 718–732, Oct. 2003.

[13] I. Akyildiz, J. S. Ho, and Y.-B. Lin, "Movement-based location update and selective paging for PCS networks," *IEEE/ACM Trans. Netw*, vol. 4, no. 4, 1996.

[14] G. Yavas, D. Katsaros, O. Ulusoy, and Y. Manolopoulos, "A data mining approach for location prediction in mobile environments," *Data Knowl. Eng.*, vol. 54, pp. 121–146, August 2005.

[15] M. S. Daskin, *Network and Discrete Location: Models, Algorithms, and Applications*. New Jork, USA: Wiley-Interscience, 1995.

[16] G. Pongor, "Omnet: Objective modular network testbed," in *MASCOTS '93: Proc. Int'l Workshop on Modeling, Analysis, and Simulation on Computer and Telecommunication Systems*. Society for Computer Simulation, 1993, pp. 323–326.

[17] H. Schulzrinne, A. Rao, and R. Lanphier, "Real Time Streaming Protocol (RTSP)," RFC 2326 (Proposed Standard), Apr. 1998. [Online]. Available: http://www.ietf.org/rfc/rfc2326.txt

[18] H. Schulzrinne, S. Casner, R. Frederick, and V. Jacobson, "RTP: A Transport Protocol for Real-Time Applications," RFC 3550 (Standard), Jul. 2003. [Online]. Available: http://www.ietf.org/rfc/rfc3550.txt

[19] J. Rosenberg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley, and E. Schooler, "SIP: Session Initiation Protocol," RFC 3261 (Proposed Standard), Jun. 2002, updated by RFCs 3265, 3853, 4320, 4916. [Online]. Available: http://www.ietf.org/rfc/rfc3261.txt

[20] S.-R. Yang and W.-T. Chen, "Sip multicast-based mobile quality-of-service support over heterogeneous ip multimedia subsystems," *IEEE Transactions on Mobile Computing*, vol. 7, no. 11, pp. 1297–1310, Nov. 2008.

ISBN: 978-1-61208-220-2