Future NetworkArchitectures of Networking of Everything

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***Abstract*—Currently, even though various and advanced networks, such as 4G/5G and IP based networks are available, there is very limited choice of networking in real communication depending on which Internet Service Provider (ISP) is selected by a user. On the Internet, there is no place to inquire about the physical address without DNS (Domain Name Service), which is a centralized service. Nowadays, there are social networks where users share their profiles including name, phone number, email address, even their information about private life. In this paper, we propose an architecture to integrate conventional networks and social networks, so that any user can find a destination without any centralized service by referring to the social network in which every device participates and shares their private information. Furthermore, we believe this concept can be extended beyond communications. In the context of Internet of Things (IoT), if those things are members of social networks, they can perform more advanced tasks, such as collaborative works. We focus on networking issues to integrate various networks, such as transparent networks, things social networks, and things centric networks, in which smart devices participate to provide advanced network services to smart things or thing-users, especially from the IoT perspective, through the conceptual model of Networking of Everything.**

Keywords-NoE; Transparent Network; PDN; Semantic Web; RDF; OWL.

I. INTRODUCTION

There are many different types of networks on the market, such as mobile telecommunication networks, IP-based data networks, etc. However, the networking principle has not changed. Even though multiple networks are available to the same device, the device of a user has no choice but to access the predetermined (pre-contractual) network, since each network is usually operated by different providers. Secondly, even though a device can access two or more different networks, this is done manually (even though now this is possible, network access is still limited). Thirdly, users have to know the address and its format of the device providing the target service. And lastly, at this time, especially in the current Internet, only IP address-routing is the service provided by ISPs, regardless of the service type. In other words, the user has to know everything: what kind of services is available, what is the name of service in each network, who from which network can provide it, how can he access the network, etc. It is already known that current networking cannot support meaningful and rich Internet of Things (IoT) service.

In the IoT, things are supposed to be intelligent, and the thing will be a user of the network which is called a thing-user in Networking of Everything (NoE). While the conventional device is allocated only an Internet address, which is connected to a specific access network on the Internet via Dynamic Host Configuration Protocol (DHCP), thing-users in NoE join thing-user social networks (defined in [4]) to share not only their names or addresses, but their capabilities, context, communicative motivation, experiences, and intentions of collaborative work with others, and then socializes to interact with other thing-users autonomously. The thing-users produce not only the digitalized information but also the varieties of reactions based on the socialized decision. The thing-user may describe its communicative motivation and convey intended meanings to other thing-users or thing-user groups using a mutually understood language such as semantic Web languages with Resource Description Framework (RDF), Ontology Language (OWL) and Extensible Markup Language (XML). The thing-user will discover a thing (or groups) which will provide a service from the thing-user community.

The Future Network (FN)-NoE also focuses on networking issues to integrate diverse networking techniques to provide the users' service requirements mentioned above: transparent networking, dynamic virtual networking, as well as social networking. Social networking is to find a target thing or things. Transparent networking is to interconnect various networks. Lastly, dynamic virtual networking, called Proximity Defined Network (PDN), is to define a temporary

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working space where thing-users can collaborate for the requested service.

In this paper, we show that the FN-NoE eventually provides the thing-user centric communication service that discovers and coordinates things to perform a collaborative work among the socialized things located autonomously within a space. The architecture and functional procedure of FN-NoE are presented in Sections II and III, respectively. We show a brief application in Section IV and conclude in Section V.

II. STATE OF ART

In recent years, the influence of the Internet has been increasing rapidly and powerfully. This seems to be due to the following factors. First, the performance of networks is becoming very powerful. Giga Internet or 5G network is no longer a dream, but a reality. Second, it is the evolution of the Web which is the most familiar to the users. The World Wide Web Consortium (W3C) extended the Web so that information is given well-defined meaning, better enabling computers and people to work in cooperation. Third, the spread of social networks has created new human relationships. Online social networking technologies enable individuals to simultaneously share information with others.

However, these attempts have faced unexpected problems, as follows. As the Internet with good performance became more widespread, IoT, which was built on the Internet, was introduced, and this resulted in a variety of devices that would become the rapid evolution of IPv4 addresses. Secondly, the semantic Web makes Web content machine understandable. However, it was found that there are too many jobs to describe everything in RDF format. Thirdly, the online-social networks also show some problems like private information disclosure.

At this stage, we have to consider how to integrate these three elements to maximize the advantage and minimize the disadvantages. In IoT, we consider a social network with only machines, or things with semantic Web which understand each other. The things will share information and can verify each other by exchanging WebIDs [6]. The content of semantic Web will be very limited information about predetermined network services; no privacy disclosure. Thus, this new Networking of Everything means the integration of the semantic Web network to communicate with network devices, social networks to share the information of network devices, and conventional networks for data transfer.

III. ARCHITECTURE

The infrastructure for the FN-NoE is constructed with the core networks, the access networks, and the regional networks. The core network and the access networks are evolved from the current networks and provide the connections to the users and the transparent connections between the regional networks, which is a virtual network to provide logical access to an intelligent socialized thing-user.

The FN-NoE can be operated over either existing legacy networks or future networks [1]. A NoE terminal located in a certain space connects to an access network and is connected

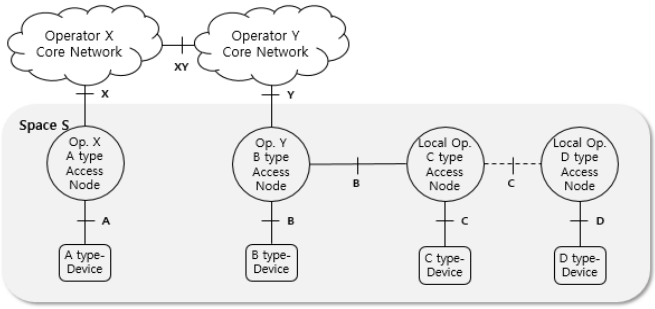

Figure 1. FN-NoE operated over existing legacy networks.

to another NoE terminal through the core networks.

The core networks between NoE terminals may be operated by different network operators and the switching and routing scheme applied to the core networks may be different. The access network is managed by the core network operator and differentiated with the type of access links and access procedures. The access network may have a local network managed by the local private owner as a subnetwork. The local network may have a local network underneath.

Figure 1 shows, excluding thing-user social network, a reference network model where multiple NoE terminals located in a certain space are connected to each other. There is an NoE terminal connected to the A type access network of the core network managed by operator X.

The FN-NoE provides (1) a transparent end-to-end connection between NoE terminals connected to heterogeneous access networks, and according to the preferred connection, (2) a thing-to-thing connection for coordinating NoE terminals autonomously. The required information for coordinating the access network in a certain space to establish a transparent connection is maintained at each NoE terminal. The NoE terminal may share the coordination information with the NoE terminals located within the same space directly or exchange in the regional virtual switch, as shown in Figure 2. The detailed information about the coordinated networking layer will be explained in the next section.

The regional networks are overlaid to the core network and the access networks. The regional networks are formed by the NoE terminals and the NoE virtual switches.

To provide transparent end-to-end connections between the NoE terminals and autonomous coordinated thing-to-thing connections among the NoE terminals, the FN-NoE

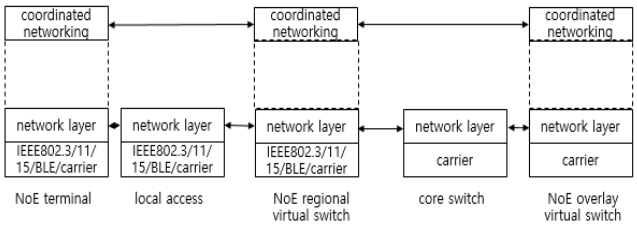

Figure 2. An example of connections in the FN-NoE

specifies following: How to manage a NoE terminal, regional virtual switch, and the overlay virtual switch? How to form a thing-user social community? How to share experience with thing-users? How to discover a thing or thing-user for collaborating? How to establish a transparent connection between the NoE terminals? And how to establish coordinated connections among the NoE terminals?

The coordinated networking layer of the FN-NoE is composed of capability blocks, as shown in Figure 3.

- **The NoE terminal resource and capability profile management** block maintains the profile and the status of the NoE terminal's resources and skill set. This block manages the status of the NoE terminal, regional virtual switch, and overlay virtual switch.
- **The NoE terminal social networking** block performs the process of forming or disbanding a social group. This block controls a NoE terminal to join or leave a social group. This block controls a NoE terminal to publish or subscribe an experience sharing with a social group. The control protocols between the NoE terminal social networking blocks are defined at the reference point R1.
- **The coordinated experience management** block maintains the coordinated networking experienced by the NoE terminal and by the NoE terminals of joined social groups. This block searches the experience base to match a request from a NoE terminal or a social group.
- **The coordinated peer discovery** block performs the process of discovering the NoE terminal to be a peer NoE terminal or the NoE terminals to form a collaborative work group. This block searches a proximal NoE terminal from a social group or hands over the discovery to the regional virtual switches or overlay virtual switches. The control protocols between the coordinated peer discovery blocks are defined at the reference point R2.
- **The transparency networking control** block manages the process of selecting preferred access networks and establishing a transparent end-to-end connection. The control protocols between the transparency networking control blocks are defined at the reference point R3.
- **The thing-user centric networking control** block manages the process of socializing a thing-user and establishing a thing-to-thing connection. The control protocols between the thing-user centric networking control blocks are defined at the reference point R4.

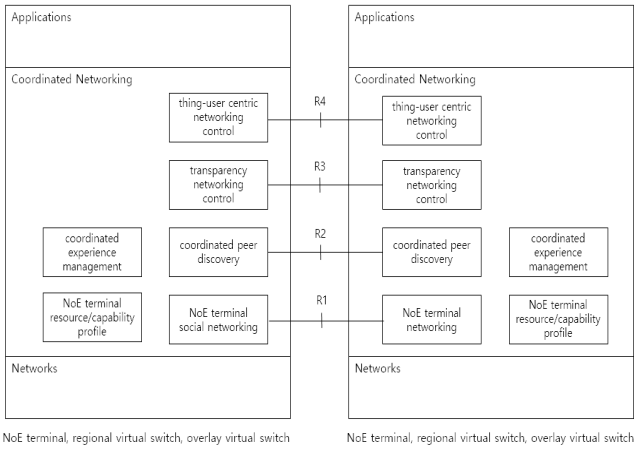

Figure 3. Reference model of the FN-NoE

IV. FUNCTIONAL PROCEDURE

The FN-NoE is composed of two main blocks: Networking of Heterogeneous Networks (NHN), which can be implemented with legacy networks, and Proximity Defined Networks (PDN) which is formed during the thing-user centric communication period

In Figure 4, nodes (or thing-users) are in the scope of three different types of access networks, i.e., heterogeneous. They may or may not communicate with each other. However, if those networks are transparent, then each device with different skills can communicate and collaborate to provide a service to a specific human-user or thing-user.

Any node like a switch, a virtual switch, a regional (virtual) switch or a network agent can be a thing-user if it can use the FN-NoE service.

A. *Thing-user social network*

In Figure 4, usually when a node (which is just legacy node) accesses the local network 1, it can communicate with a node in network 3 if a node knows its destination network address (or name) and networks should be interconnected via intermediate nodes. When the networks are physically located too far away, it is a very time-consuming job.

However, when thing-user 1 (very smart node) in Figure 4 joins an appropriate social network 1 depending on its profile and objectives, it can locate the exact thing-user in network 3, not by network- dependent routing algorithm, but by context-aware social networking, as shown in Figure 5.

By this thing-user social networking, a transparent networking service is provided to the thing-user, which is only identified by a profile or name (not network address).

Of course, if it can not find its social group, it itself must create and post it to the regional post and/or the global post, if needed, to announce it to others.

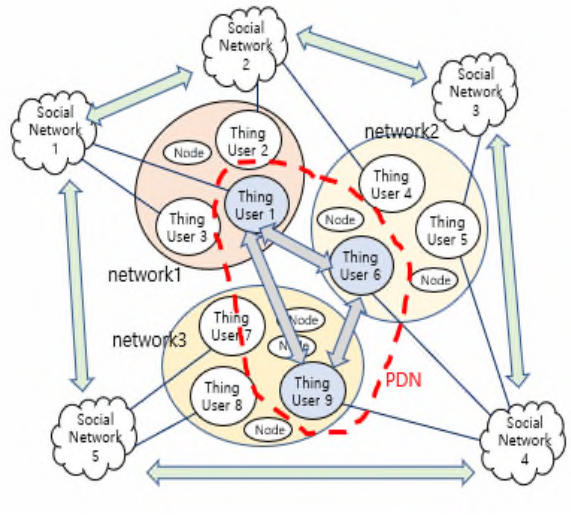

Figure 4. FN-NoE conceptual model

Note that even though the matter to create, find, and maintain the social networking is out of scope of this work, they are key procedures to be defined in other documents.

B. *Transparent end-to-end connection*

The FN-NoE allows a NoE terminal to select appropriate access networks according to the preferred connection and to establish a transparent end-to-end connection between the NoE terminals. The FN-NoE defines the coordinated networking layer located at the OSI application to provide transparent end-to-end connections between NoE terminals and autonomous coordinated thing-to-thing connections. The coordinated networking layer supports the NoE terminal to be socialized for sharing the coordination experience and for performing context-based discovery and establishing a connection.

The regional virtual switch supports a NoE terminal for discovering an appropriate access network and provides access network to establish a transparent connection. The overlay virtual switch performs a hierarchical peer-to-peer overlay switching for exchanging coordination information between regional virtual switches to provide a transparent end-to-end connectivity between the NoE terminals.

C. *Proxmity defined network*

Figure 6 shows that when a thing-user locates its destination thing-user or thing-user group, using thing-user social networking, it explains its profile or objectives, and then requests collaboration from its counterpart thing-user(s) in PDN, as shown in Figure 4. If it needs additional thing-users, then it will request to find more thing-user(s) in the near social group, recursively.

PDN is a sort of temporary virtual network in which a group of thing-users collaborate with each other autonomously during the thing-user central communications.

D. *Thing-user centric communication*

The thing-user centric communication service is accomplished over PDN, which is based on thing-user social networking. The thing-user communicates with another thing-user or a thing-user group in PDN by conveying the intended meaning, which describes the communication motivation, and experience on a specific task by ontology-based thing-user language. The thing-user discovers a communication party, relying on the assistance of thing-users of a thing-user social group, requests to introduce a thing-user who may be the communicative correspondent or might know the communicative correspondent until it meets the right communication party. The social assistance is accepted upon the trust and reputation of a thing-user acquired in a social group. Currently, in our application, the trust and reputation can be achieved with WebID and semantic inference.

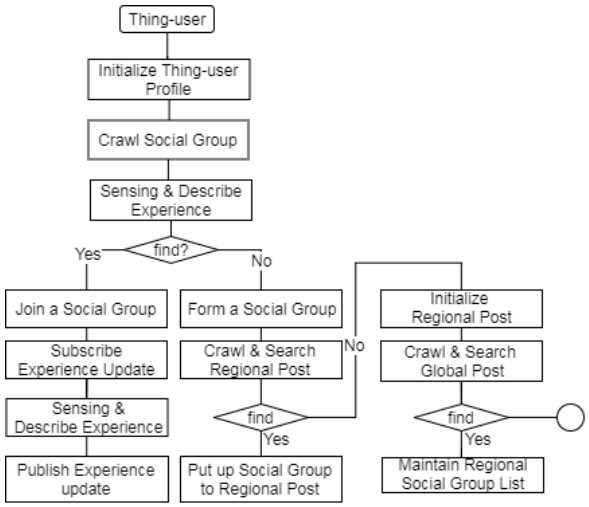

Figure 5. Functional procedure of thing-user social networking

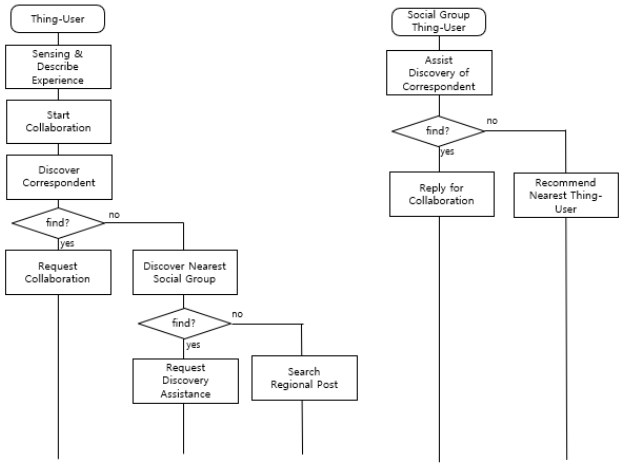

Figure 6. Functional procedure of Proximity Defined Networking

V. APPLICATION

In this section, we briefly introduce an application which was built over a very preliminary NoE architecture [5], namely, an autonomous collaboration system of smart things using accumulated experience knowledge achieved by semantic inference with RDF database.

In Figure 7, smart delivery service with a drone having smart thing's structure is shown as one of services over the autonomous collaboration system.

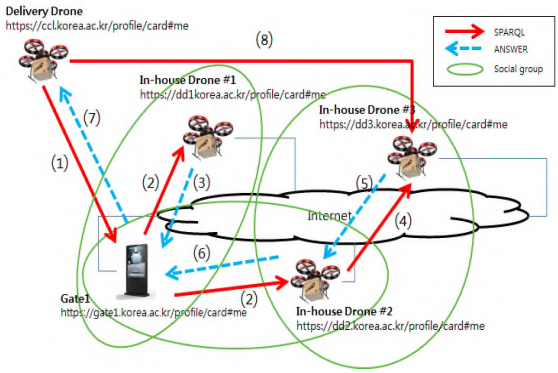

Figure 7. Example of collaborative service over NoE

If all Smart Things have Basic Identity Information (BII) and use semantic technology, the Internet can become the world of Smart Things, which has built up many social networks. Semantic technology provides a way to utilize the new Web application of many Smart Things connected to the Internet. In this paper, we show a mailing and delivery collaboration system among drones as a specific task of spatial autonomous collaboration where Smart Things collaborate using semantic technology, such as SPARQL (a semantic query language for Database) [7]. If a Smart Thing has BII composed of a Web server address, WebID, and endpoint address, and can query SPARQL for a purpose, it shows how spatial autonomous collaboration is possible in intelligent Web without special environment or Artificial Intelligence (AI). The delivery drones that come with the mail look for collaborative in-house drones using BII, Identification Process (IDP), and SPARQL semantic techniques based on the Default Response Rules (DRR).

Smart Thing updates the BII of collaborators in TDB-Experience knowledge after collaboration. It accumulates a collaborative experience and expands its social network. The delivery drones which experienced collaborations with company drones # 3 were able to deliver mail more quickly and accurately by utilizing their experience knowledge when the same task occurred. Thanks to the accumulated experience knowledge, it is possible to process the same thing more quickly and accurately in the future.

VI. CONCLUSION AND FUTURE WORK

Networking of Everything (NoE) refers to the process capable to provide FN-NoE services, such as transparent network service, thing-user social network service, and thing-user centric communication service to the thing-users who participate in the FN-NoE. In other words, the distributed social networking of thing-user devices will provide thing-user centric service which is supported by the intelligence and semantic knowledge of the thing-user.

The given application is implemented and verified under the assumption that a delivery social network has already been established. Depending on the purpose, how to establish and dismiss the social network over FN-NoE would be one of our future works.

Problems related to the NoE were defined in ISO/IEC TR 29181-9 in 2017. Even though this paper is a very preliminary stage for its solution, enhanced work on NoE is to be proposed as International Standards on NoE architecture and its companion protocols.

ACKNOWLEDGMENT

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