Random Access Design for Clustered Wireless Machine to Machine Networks

Newsletter No. 30
October 2013

Introduction

This article introduces a design for clustered wireless machine-to-machine (M2M) networks in order to handle the massive amount of transportation between M2M applications. The clustered M2M network structure can fully reuse the random access resource spatially among clusters to increase the number of machines supported by the network and reserve more random access resource for the conventional devices.

In recent years, the convenient wireless connection between personal mobile devices has been gradually extended to connecting appliances in everyday life to provide spontaneous services and better living experiences. In the near future, the appliances will be equipped with the capabilities to sense and monitor people's daily needs, and to self-configure via network connections to serve the needs. Seamless machine-to-machine (M2M) wireless connection is the key to sustaining such sophisticated and large-scale interconnections between the machines. Various M2M applications have been proposed recently. While there are some M2M applications that maintain only a few machines which continuously transmit medium to high data rates (e.g., video surveillance, digital signage), there are other M2M applications that require a large number of machines with infrequent, bursty, and low-priority (non-emergency) transmissions. For example, in the urban area, there could be tens of thousands of smart meters in the coverage of a macro cell, where a few hundred bytes of data are sent once a second. The characteristics of this type of M2M applications are against the design

Monthly Events

- Dr. Fred Jiang, the Chief Architect of China Intel IoT Joint Labs / Senior Staff Researcher at Intel Labs China, gave a talk, "Internet of Things and its Applications in Smart and Sustainable Living" on October 2nd 2013.

- Dr. Yanzhen Qu, the director of Engineering Department in Colorado Technical University, led a seminar regarding the effective methodologies for science and technology researches on October 3rd 2013.

Dr. Qu's visit on October 3rd 2013

concept of many existing wireless networks (e.g., LTE) which were designed to accommodate a relatively small number of high-rate users per access point/base-station with continuous data with full-buffer traffic queues. Therefore, the currently known wireless network designs are unlikely to be able to handle the M2M applications with a large number of machines. For example, the random access channels (RACH) and control channels of LTE may not have enough capacity to accommodate the large amount of accesses from the smart meters in the cell.

To accommodate large amount of M2M random accesses in the LTE-Advanced machine-type communication (MTC), the access class barring (ACB) and extended access barring (EAB) techniques have been proposed previously in the 3GPP standards. For the one-shot random access attempts which correspond to the extremely low-duty-cycle scenarios where the network has enough time before the next traffic burst to resolve random access collisions, ACB and EAB have been shown to be sufficient if the machines can tolerate long access delay. However, when the machine traffic is recurrent with higher duty cycle, the ACB and EAB will fail to resolve collisions before the next wave of traffic comes in.

Based on a clustered M2M network structure in which the machines in a macro cell are divided into clusters, and the machines belonging to a cluster communicate to the cluster head which then aggregates the traffic and relays to the macro base station (see Fig. 1, and more details in [1], [2]), the team led by Prof. Hsuan-Jung Su and Prof. Hung-Yun Hsieh investigated how the clustered M2M network can spatially reuse the random access resource to increase the number of machines supported by the network and/or reserve more random access resource for the conventional (human) devices.

For the contention-based random access, there are four operational steps. The first step is transmitting a random access preamble. The random access preambles are generated by one or more root Zadoff-Chu sequences. However, root Zadoff-Chu sequences are not necessarily orthogonal. When the random access preambles for human devices and machines are generated by different root Zadoff-Chu sequences, they will interfere with each other. Since the coverage of a macro base station is much larger than the coverage of a cluster, the transmitted power of human devices is much larger than that of machines, i.e., human devices cause severe interference to machines. Therefore, the random access preambles for human devices (and cluster heads) and machines should be generated by the same root Zadoff-Chu sequence to avoid interference. In addition, when the same random access preamble is utilized for machines in neighbor clusters at the same time, it might cause the inter-cluster interference. Nonetheless, based on the analysis in [3], the inter-cluster interference will not affect the random access results. Therefore, full reuse of the random access resource among clusters is feasible.

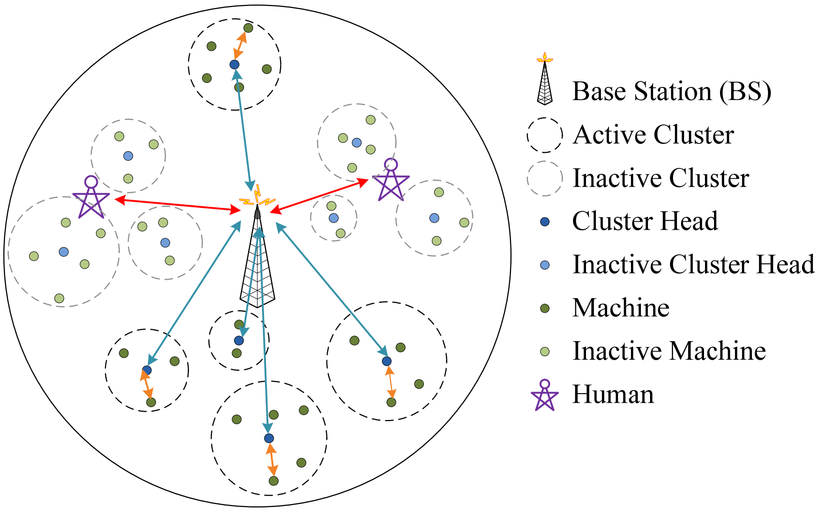

Figure 1: A clustered M2M wireless network.

To evaluate the performance of the clustered random access, simulations were performed with parameters given in the 3GPP LTE-Advanced MTC standards. According to the simulation results, the number of clusters that should be formed and the number of random access preambles that should be allocated to the machines can be obtained when the total number of machines is given. Fig. 2 shows the number of successful random access machines (y-axis) out of a given total number of machines (x-axis) for various numbers of preambles. For example, 24 preambles can support about 4000 machines per cluster. Therefore, at least 8 clusters should be formed to achieve 100% success probability if there are 30000 machines and 24 preambles for the machines.

In summary, analysis and numerical results verified that the clustered M2M network structure can fully reuse the random access resource spatially among clusters to increase the number of machines supported by the network and/or reserve more random access resource for the conventional (human) devices.

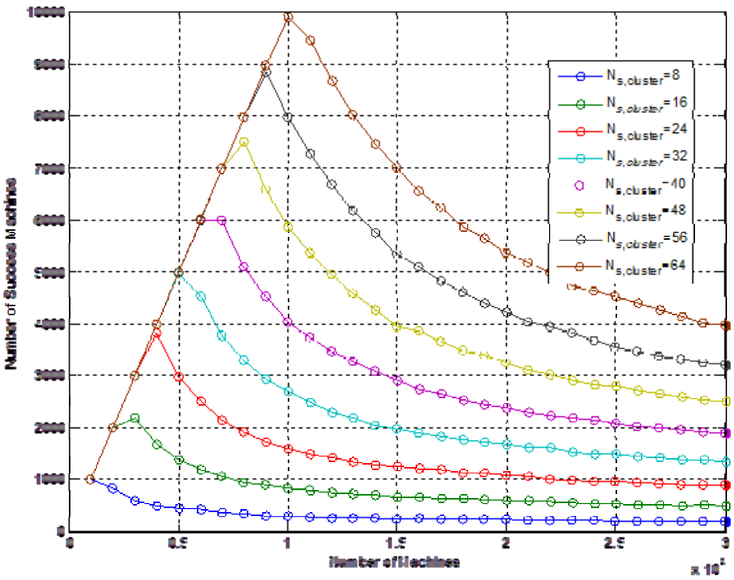

Figure 2: The numbers of successful machines for various numbers of preambles.

Reference

[1] S.-E. Wei, H.-Y. Hsieh, and H.-J. Su, "Enabling dense machine-to-machine communications through interference-controlled clustering," in *Proc. International Wireless Communications and Mobile Computing Conference (IWCMC)*, Aug. 2012.

[2] S.-E. Wei, H.-Y. Hsieh, and H.-J. Su, "Joint optimization of cluster formation and power control for interference-limited machine-to-machine communications," in *Proc. IEEE Global Communications Conference (GLOBECOM)*, Dec. 2012

[3] S.-H. Wang, H.-J. Su, H.-Y. Hsieh, S.-P. Yeh, and M. Ho, "Random access design for clustered wireless machine to machine networks," in *Proc. First International Black Sea Conference on Communications and Networking (BlackSeaCom)*, July 2013.

About the Author(s)

Hsuan-Jung Su, Professor,

Department of Electrical Engineering and Graduate Institute of Communication Engineering, National Taiwan University

SIGARC PI, Intel-NTU Connected Context Computing Center

Hung-Yun Hsieh, Associate Professor

Department of Electrical Engineering and Graduate Institute of Communication Engineering, National Taiwan University

SIGARC Co-PI, Intel-NTU Connected Context Computing Center

Sen-Hung Wang, Post-doctoral Researcher

Intel-NTU Connected Context Computing Center

Intel-NTU Connected Context Computing Center

BL-7C, Barry Lam Hall,
1 Roosevelt Road, Sec. 4
National Taiwan University
Taipei, 10617 Taiwan
Tel: +886-2-3366-1467

http://ccc.ntu.edu.tw

Acknowledgements

This work was jointly supported by National Science Council, National Taiwan University and Intel Corporation under Grants NSC101-2911-I-002-001 and NTU101R7501-1.