

**Taikichiro Mori Memorial Research Grants 2016
Graduate Student Researcher Development Grant Report**

Research Project:
Development of a Duplex Cloud/Crowd Database System

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Research Outline

Massive amounts of data are being generated by sensor nodes deployed in various fields. In the Wireless Sensor Networks (WSN) layer, a model of sensor nodes-master controller for sensory data collection has been demonstrated in [1]. An algorithm for low-power sensor node has been proposed in to improve the lifespan of sensor nodes with ZigBee interface [2]. In case of long-range tracking, sensor nodes using LoRa has been used [3]. Normally, these Big Data are collected and uploaded to the Cloud for further operations such as data processing and data analysis. However, for real-time data logging and delay-sensitive applications, uploading large amount of sensors data instantly into the Cloud is inefficient in term of data traffic and system reliability. Instead of uploading data directly into the Cloud, data can be preprocessed in an intermediate layer called Fog Computing. Fog Computing is an extended computing on the network edge. It assists networking, computing and storage between the end devices and Cloud Computing data center, which can be carried out by smart gateways [4]. Our goal is to develop highly scalable and reliable Fog Gateways for Cloud/Crowd system back-end which will be integrated with large scale Wireless Sensor Networks (WSN).

Research Design and Outputs

We proposed a novel system called “Cloud/Crowd System” which integrates large scale data aggregation and retrieval. A hierarchical architecture of Fog Computing is applied to expand the system scalability. The proposed system realizes congregation of data by gateways in which data are collected into a group or crowd, before being sent and stored in Cloud repositories. Selected data are sent back to the crowd (or users) as a feedback. Figure 2 shows the overview of Cloud/Crowd System.

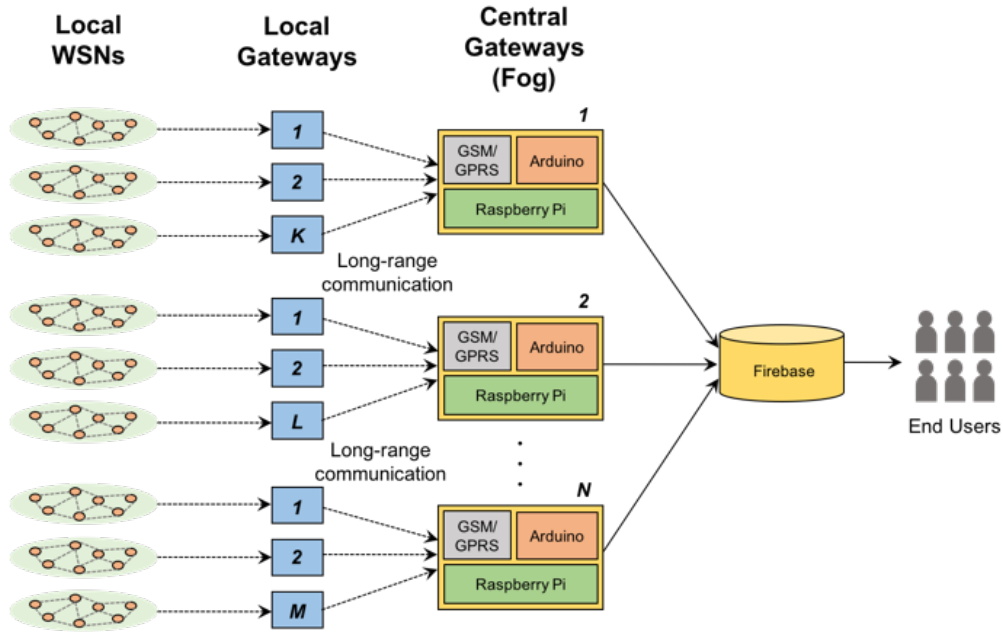


Fig. 1. Overview of the Cloud/Crowd system

We assume the deployment of a large scale Wireless Sensor Networks (WSN) in wide and remote areas. The gateways are categorized into two kinds; 1) Local Gateways and 2) Central Gateways. Local Gateways are assumed mobile and have constraint in internet connection, meanwhile the Central Gateways (Fog Gateways) are fixed and have the ability of accessing the internet. The roles of Local Gateways are to collect local individual data from sensor nodes and process them into bulk data. Meanwhile, Central Gateways aggregate the bulk data from Local Gateways and process them before being stored in the Cloud.

To improve the system adaptability to internet-free environments, long-range wireless communication protocol is exploited to guarantee a long-range data transmission between Local Gateways and Central Gateways. In this work, we focused on the Cloud/Crowd system back-end for monitoring and reporting the number of livestock animals. The system back-end consists of Central Gateways and Cloud database. The roles of data aggregation, processing and retrieval from the Cloud in the system back-end are performed by the Central Gateways. Figure 2 shows the proposed system scheme.

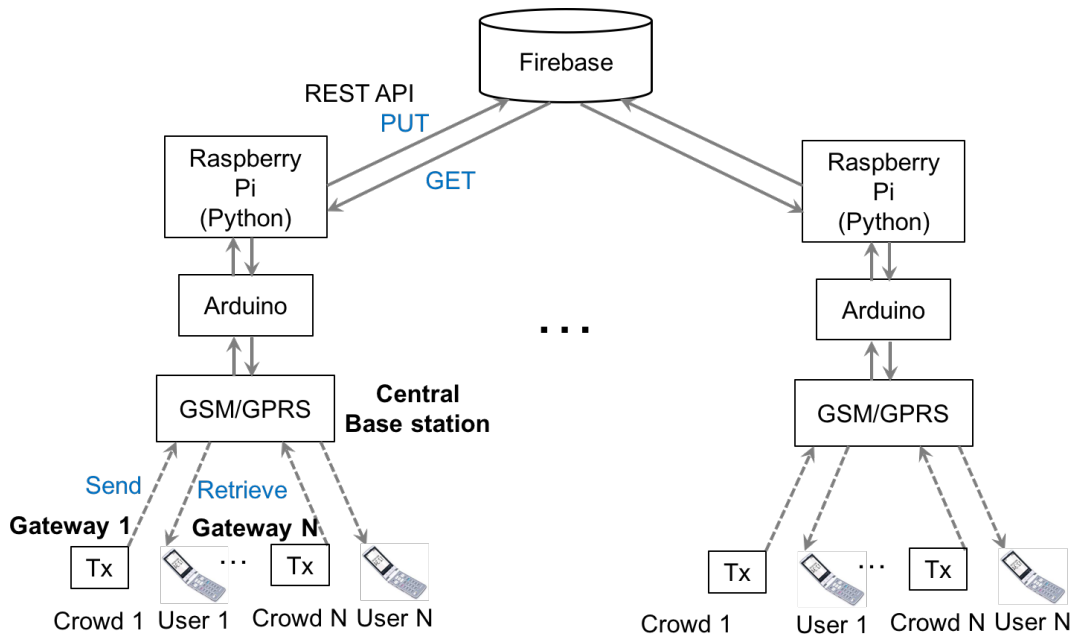


Fig. 2. Proposed System Scheme

We conducted few tests on the wireless communication between local Gateways and Central Gateways as well as the data uploads into the Cloud database. The procedure for system development in this research are summarized as follows:

- 1) Sending/Receiving SMS from local Gateway to Central Gateway through GSM/GPRS wireless communication

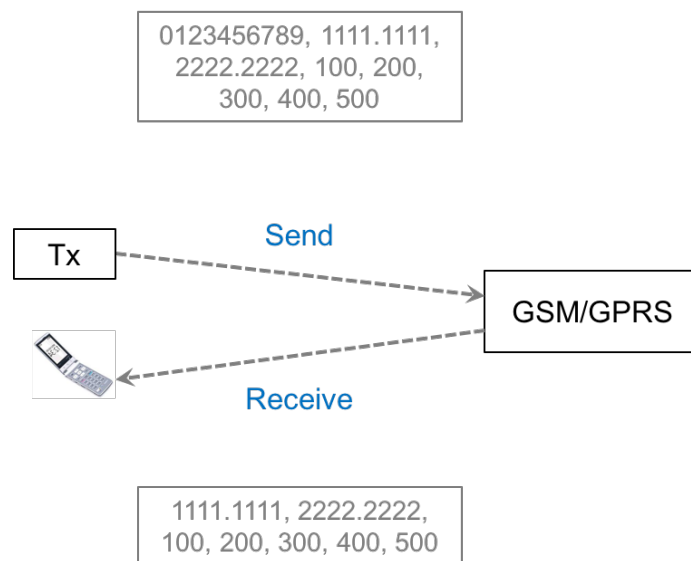


Fig. 3. Wireless Communication

2) Storing Data to FireBase

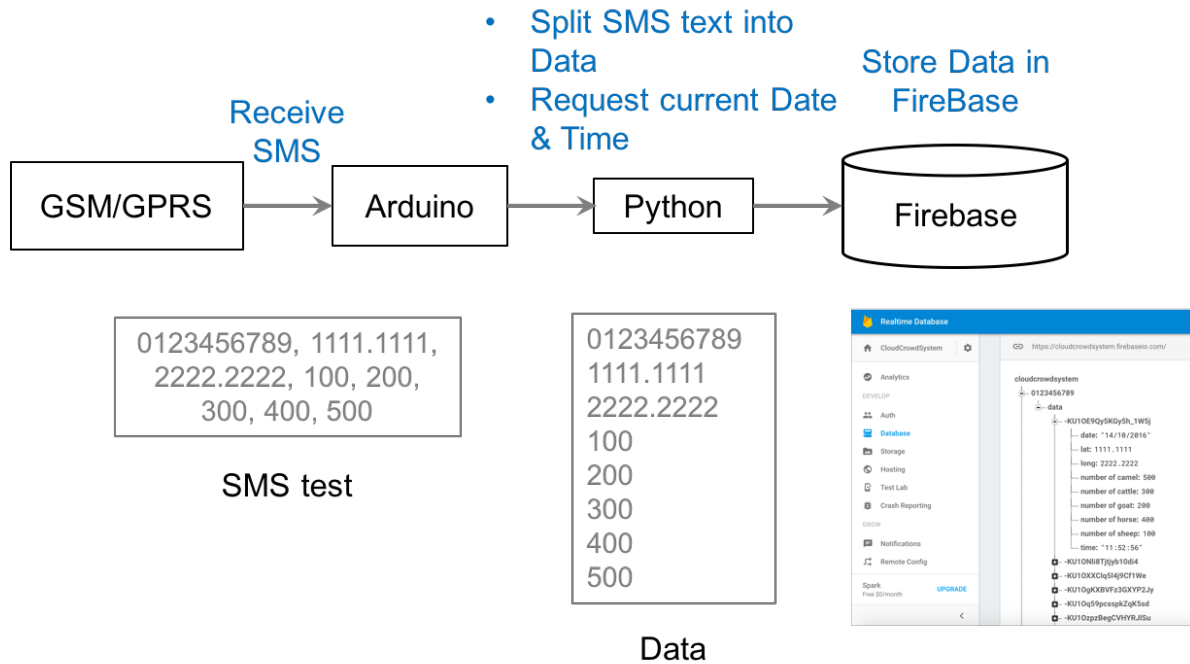


Fig. 4. Data Processing and Management

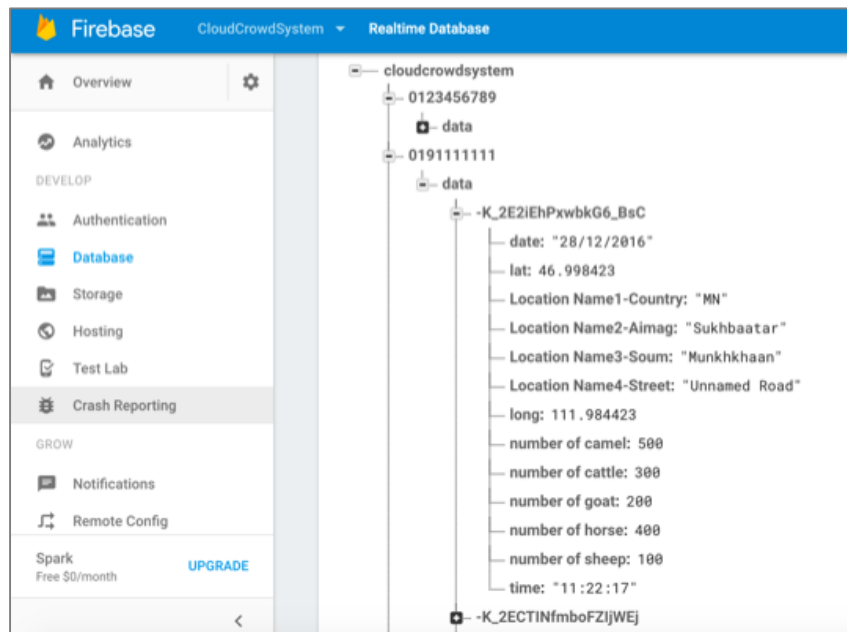


Fig. 5. Example of data stored inside FireBase's real-time database

Conclusion

In this research, we introduced a new scheme of Fog Gateways as a medium for Fog Computing in the Cloud/Crowd system back-end. The deployment of the proposed Fog Gateways supports larger integration of Wireless Sensor Networks (WSN) with Cloud services. The system prototype is fully developed by using open-source hardware and open source cloud database. The developed system is highly scalable therefore, significant for a large scale system that requires high reliability in its data communication processing.

Future Work

As an extend of this study, we are interested to study and evaluate the system performance of by conducting experiments. This requires more gateway prototypes to be developed and tested in real testbeds.

Acknowledgement

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References

- [1] M. Saari, A. M. Baharudin, P. Sillberg, P. Rantanen, and J. Soini, "Embedded Linux controlled sensor network," in *2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics, MIPRO 2016 - Proceedings*, 2016, pp. 1185–1189.
- [2] K. T. Ahmad Muzaffar bin Baharudin, M. Saari, P. Sillberg, P. Rantanen, and J. Soini, "Low-energy algorithm for self-controlled Wireless Sensor Nodes," in *The International Conference on Wireless Networks and Mobile Communications 2016 (WINCOM'16)*, 2016.
- [3] A. Muzaffar and W. Yan, "Long-Range Wireless Sensor Networks for Geo-location Tracking : Design and Evaluation," *18th Int. Electron. Symp. (IES), Bali, Indones. 29-30th Sept. 2016*, no. September, 2016.
- [4] M. Aazam and E. N. Huh, "Fog computing and smart gateway based communication for cloud of things," in *Proceedings - 2014 International Conference on Future Internet of Things and Cloud, FiCloud 2014*, 2014, pp. 464–470.

Publications

Peer-Reviewed International Conference Proceeding:

- 1) M. Saari, Ahmad Muzaffar bin Baharudin, P. Sillberg P. Rantanen J. Soini, "Embedded Linux Controlled Sensor Network", 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, May 25-29, 2016.
- 2) Ahmad Muzaffar bin Baharudin, Wanglin Yan, "Long-Range Wireless Sensor Networks for Geo-location Tracking: Design and Evaluation", 2016 International Electronics Symposium (IES), Bali, Indonesia, September 29-30, 2016.

- 3) Ahmad Muzaffar bin Baharudin, Mika Saari, Pekka Sillberg, Petri Rantanen, Jari Soini, Tadahiro Kuroda, "Low-Energy Algorithm for Self-Controlled Wireless Sensor Nodes", The International Conference on Wireless Networks and Mobile Communications 2016 (WINCOM'16), Fez, Morocco, October 26-29, 2016.
- 4) Ahmad Muzaffar bin Baharudin, Mika Saari, Pekka Sillberg, Petri Rantanen, Jari Soini, Hannu Jaakkola, Wanglin Yan, "Development of Fog Gateways for Cloud/Crowd System Back-End", International Black Sea Conference on Communications and Networking, Istanbul, Turkey, June 5-8, 2017. (Submitted)
- 5) M. Saari, A. Muzaffar bin Baharudin, S. Hyrynsalmi, "Survey of Prototyping Solutions Utilizing Raspberry Pi," 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, May 22-26, 2017. (Submitted)