International Journal of Scientific Engineering and Technology ISSN:2277-1581
Volume No.5 Issue No.8, pp: 421-424 01 August 2016

Application Protocols of Wireless Sensor Networks (WSNs) for Smart Grid Applications

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Abstract : Wireless Sensor Networks are one of the enabling technologies to realize the next generation electrical power grid called "Smart Grid". Smart Grid provides the facility to integrate the advancement of information and communication technology with sensor technology to make the grid really smart, robust and adaptive. In spite of all these advancement, it is the application protocol that makes the technology useful to the end user either human or machine. Hypertext Transfer Protocol (HTTP), the internet's de'facto application protocol is not efficient for WSN based smart grid applications due to bandwidth and energy inefficiency. Constraint Application Protocol (CoAP) and Message Queue Telemetry Transport (MQTT) are two candidate application protocols that can be used for smart grid application. In this Paper, We compare these three protocols applicability for smart grid application

Keywords— Wireless Sensor Networks (WSNs), Constraint Application Protocol (CoAP), Message Queue Telemetry Transport (MQTT), Smart Grid.

I. INTRODUCTION

The rapid growth of world population, industrialization and urbanization increase the electricity demand manifold which put heavier load on the already overstressed and fragile electricity infrastructure. In addition, the existing electric power also suffers from the lack of pervasive and effective communications, monitoring, fault diagnostics, and automation, limited real-time information about the dynamic change in load and operating conditions of the system which further increase the possibility of region-wide system breakdown due to the cascading effect initiated by a single fault [1]. Moreover, the adaption of distributed and renewable (Solar, Wind etc.) energy sources to the main power grid introduced many new challenges such as energy storage, system stability and energy integration. To overcome these challenges, a new concept of next-generation electric power system, a smart grid, has emerged [2]. A smart grid is an "intelligent" electrical energy distribution network that employ bi-directional communications, advanced sensors and controls, advanced meters to improve the efficiency and reliability of the electricity grid, facilitate the connection of distributed generation facilities to the system, optimize the integration of renewable energy systems and help to reduce customers' energy uses. It also includes in-home energy management systems and intelligent controls in appliances, giving consumers more choice and control over how and when electricity is used, which can save money and help the utility companies operate its electricity network more efficiently and reliably for the benefit of all its customers.

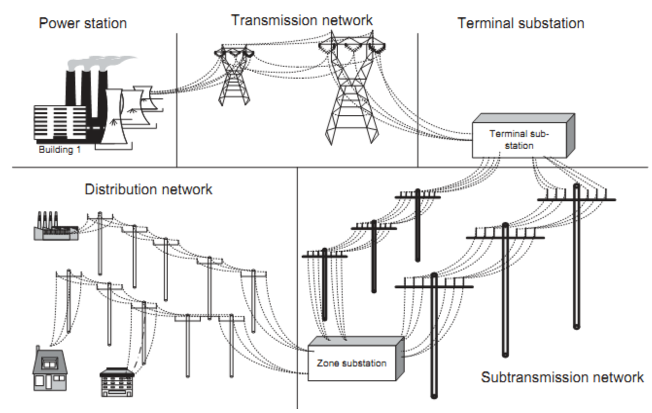

Figure 1: Traditional Electric grid system

A robust and scalable communication infrastructure is the heart of the grid that will make the conventional electrical grid into an intelligent and adaptive smart grid. However, the conventional communication networks and its protocol cannot be directly applied for smart grid communication because of its different application characteristics and traffic requirements. The modern telecom system are optimized to support various applications such as web browsing, email, large file transfer, voice over IP (VoIP) or streaming multimedia. However, in the smart grid scenario, the traffic pattern and application requirements are quite distinct. The grid network should be optimize to support communication among a large number of smart meters, many sensor and actuators, Intelligent Electronic Devices (IEDs),distributed into a large geographic area with minimum human interaction. These machine-to-machine (M2M) type communications are mostly autonomous and periodic as well as event driven [3]. Therefore, the collaborative and low-cost nature of wireless sensor networks (WSNs) bring significant advantages over traditional communication technologies used in today's electric power systems. Hence, WSNs have been considered as a promising and complementary technology for various smart grid applications such as load management and control, wireless automatic meter reading (WAMR), equipment fault diagnostics, remote monitoring, electric fault detection, and distribution automation. IEEE defines a standard named IEEE802.15.4std,[4] for low power, low cost WSNs physical and medium access control (MAC) layer protocol that can be applied in smart grid application. However, to get all the benefits from WSNs for smart grid applications, its require application protocols that are bandwidth, energy and resource efficient. In this paper, we compare three application layer protocol namely, Hypertext Transfer Protocol (HTTP), Constraint Application Protocol (CoAP) and Message Queue Telemetry Transport (MQTT) for various smart grid application.

II. MAJOR SMART GRID APPLICATIONS AND APPLICATION LAYER PROTOCOLS

From Power System Perspective, smart grid has generation, transmission, distribution and consumptions domain and its applications. From communication and networking perspective, smart grid is the composition of wide area network (WAN), Neighbourhood Area Network (NAN) and Home Area Network (HAN) depends on the data rate and coverage [5].

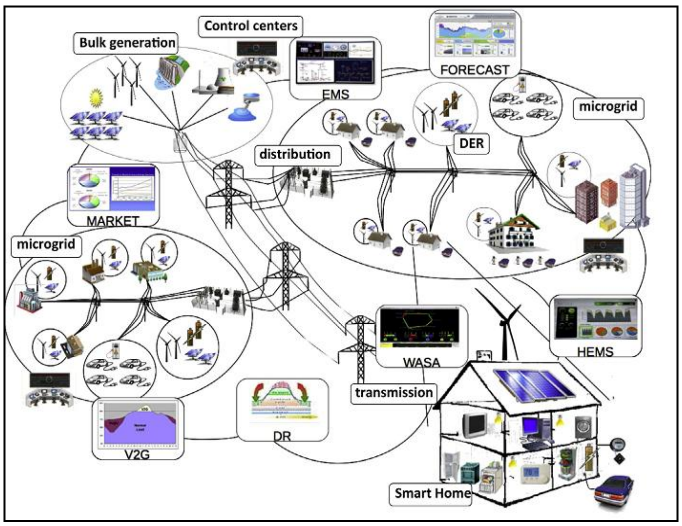

Figure 2: Reference model of a smart grid [6]

Many applications can be deployed across the smart grid based on this classification. For example,

Two way Communications

Smart grid system provides two way communication networks to exchange data among the systems (Generations, transmissions, distributions and end users), the smart meters and sensors to enable different smart grid applications.

Demand Response

Demand response aims to reduce the end users energy consumption during the high demand time, that happens in some periods of the day called the peak hours. With the advancements of the Smart grid technologies, the residential users will have the opportunity to participate in a demand response program, depending on a contract made in advance which determines when and how to reduce the user load, the utility systems will have the ability to manage the end user appliances and adjust the smart user devices, therefore, the utility generators keep providing its desired service in the peak hours .

Renewable energy and Electric Vehicle Integration

The burning of fossil fuels (coal, oil, gas) to produce electric energy is one of the major causes of global warming and climate changes. For this reason nowadays, the governments and utility companies are encouraged to use renewable sources of energy like solar and wind. Many new buildings/houses are nowadays installed with Photovoltaic solar panel. These smart buildings/homes may also have some type of storage to store energy. The home appliances may use power either directly from the power grid or from the renewable energy storage based on the user preference that may depends on other factors like electricity prices or the time of the day. Even the consumer can sell the electricity back to the grid. However, how to use this energy intelligently, it requires to implements a reliable communication network that integrate the renewable sources with the power grid and end user.

The increasing penetration of small distributed energy resources, like residential photovoltaic panels, in combination with an expected increase of electric vehicles and relative charging stations is causing severe management issues to the distribution grid. The Smart Meters deployed over the distribution grid create a Sensor Network used for grid control and management. The intelligent unit employed in the proposed system is able to communicate using standard metering protocols allowing high-level integration with systems that use this information for both billing and customer relationship management – as is today with Automatic Meter Management systems – and for the technical management of the LV power infrastructure like Distribution Management Systems.

Impact of the EV penetration If charged at parking lots or customer premises, the distribution grid is the part where most electric vehicles will be attached to. Uncontrolled EV charging could stress the distribution grid and cause system failures such as transformer and line overloading deteriorate power quality (e.g., large voltage deviations, harmonics, etc.). Intelligent control mechanisms with wireless sensor networks can mitigate the aforementioned effects. Such framework requires both parties (EVs and the grid) to communicate.

Major Smart grid applications are shown in Fig 3:

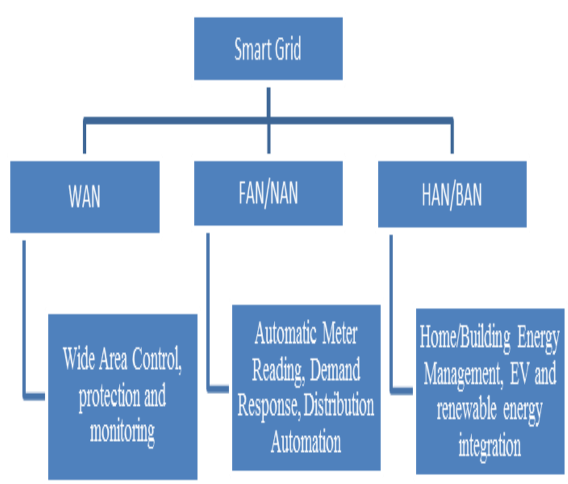

Figure 3: Major Smart Grid Applications

Many Applications can be realized using wireless sensor networks. However, WSNs requires application protocols that are bandwidth, energy and resource efficient. Message Queue Telemetry Transport (MQTT) [7] and Constrained Application Protocol (CoAP) [8] are two such protocols gaining popularity for real-world WSN deployment scenarios. These two protocols along with HTTP protocol are discussed below:

Hypertext Transfer Protocol (HTTP)
The HTTP is an application–level stateless protocol for data exchange over internet. HTTP protocol usage a request-response messaging model in the client-server computing paradigm. Clients (a web browser) submit HTTP requests to the server (an application running on a computer) and the server returns a HTTP response providing the requested resources like html, image file or query results. This simple, media independent and stateless protocol are the foundation of the World Wide Web (WWW). However, in spite of being robust and scalable, HTTP requires more bandwidth and energy which is a great problem for constraint device.

Constrained Application Protocol (CoAP)
The Constrained Application Protocol (CoAP) is a lightweight application protocol to transfer data from a large number of constrained nodes and constrained networks like smart grid wireless sensor networks. The protocol is designed to use minimal resources, both on the device and on the network. Instead of a complex transport stack, it gets by with UDP on IP. A 4-byte fixed header and a compact encoding of options enables small messages that causes no or little fragmentation on the link layer. Many servers can operate in a completely stateless fashion. CoAP is based on the wildly successful REST model: Servers make resources available under a URL, and clients access these resources using methods such as GET, PUT, POST, and DELETE. Also CoAP defines four types of messages: Confirmable, Non-confirmable, Acknowledgement, Reset. Confirmable message ensure the reliability by a simple retransmission mechanism using an exponential backoff when do not get any acknowledgement from the recipients with the same message ID.

Message Queue Telemetry Transport (MQTT)
Message Queue Telemetry Transport (MQTT) protocol is also an application layer protocol designed for resource-constrained devices. It uses a topic-based publish-subscribe architecture. This means that when a client publishes a message to a particular topic, then all the clients subscribed to the topic will receive the message. Like Hypertext Transfer Protocol (HTTP), MQTT relies on Transmission Control Protocol (TCP) and IP as its underlying layers. However, compared to HTTP, MQTT is designed to have a lower protocol overhead. The reliability of messages in MQTT is taken care by three Quality of Service (QoS) levels. QoS level 0 means that a message is delivered at most once and no acknowledgement of reception is required. QoS level 1means that every message is delivered at least once and confirmation of message reception is required. In QoS level 2, a four-way handshake mechanism is used for the delivery of a message exactly once.

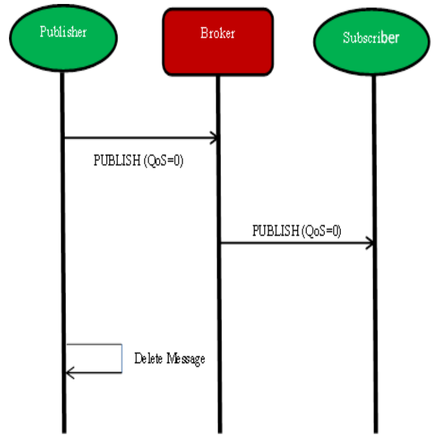

Figure 4: MQTT PUBLISH Message (QoS 0)

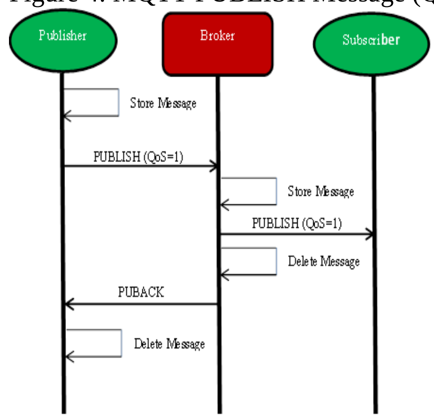

Figure 5: MQTT PUBLISH Message (QoS 1)

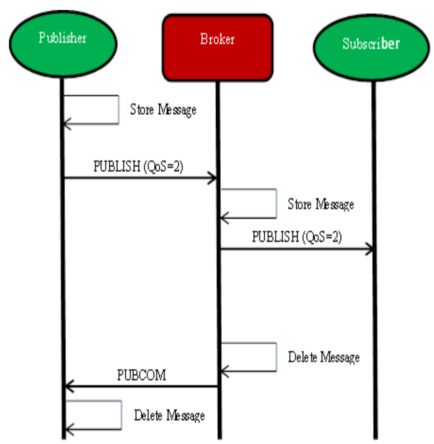

Figure 6: MQTT PUBLISH Message (QoS 2)

MQTT distribute the message based on specific topics, topic trees, and topic strings. A topic defines the content of a message or the subject area under which the publisher publish a message The subscriber subscribe to a particular topic to receive every message published on that topic from any publisher. The topics are organized hierarchically into topic trees, using the '/' character to create subtopics in the topic string. A topic string is a character string that identifies the topic of a publish/subscribe message.

III. COMPARISON OF HTTP, CoAP AND MQTT

In [9, 10], the author shows a preliminary performance comparison between MQTT and CoAP protocol. The results show that MQTT exhibits lower delay compared to COAP for lower packet loss. Other Hand, CoAP consumes less bandwidth than MQTT to transmit the same payload size.
The following table summarizes the comparison of HTTP, CoAP and MQTT protocol:

Table 1:
Comparison of HTTP, CoAP and MQTT

	HTTP	CoAP	MQTT
Pattern	Request/Response	Request-Response, Resource Observe	Publish/Subscribe
Transport Layer	TCP	UDP	TCP
Quality of Service	NO	Two QoS Level: confirmable messages" and "non-confirmable messages	Three QoS Level. 0:Fire and Forget 1: At least Once 2: Exactly One Time delivery
Data Distribution	One-to-one	One-to-one, one-to many	One-to-one, one –to-many, many-to-many
Caching	Yes	Yes	No
Discovery	Yes	Yes	No

IV. CONCLUSION

In this paper, three application protocols HTTP, CoAP and MQTT are discussed for different wireless sensor networks based smart grid applications. CoAP and MQTT both are efficient compare to HTTP for constraint networks and devices. However, CoAP is based on UDP and lightweight whereas MQTT is based on TCP which gives MQTT preference for reliable applications. Smart Grid needs to support diverse application with different requirements. Thus it is necessary to develop a multiprotocol system to leverage the benefit of all these protocols.

ACKNOWLEDGEMENT

The authors would like to thank The Ministry of Higher Education (MOHE), Malaysia for the research grant ERGS13 023 0056 Entitled: "Development of Novel Wireless Sensor Networks (WSNs) for Smart Grid Low Voltage Distribution Automation Systems (LVDAS).

REFERENCES

i. *V. C. Gungor, "Opportunity and Challenges of Wireless Sensor Networks in Smart Grid", IEEE Transactions on Industrial Electronics, Vol. 57, No. 10 pp.3557-3564, Oct. 2010*

ii. *V. Gurkan Tuna,V. Cagri Gungor,and Kayhan Gulez.,"Wireless Sensor Networks for Smart Grid Applications : A Case Study on Link Reliability and Node Lifetime Evaluations in Power Distribution Systems", International Journal of Distributed Sensor Networks Volume 2013, http://dx.doi.org/10.1155/2013/796248*

iii. *Reduan H. Khan, Jamil Y. Khan, "A comprehensive review of the application characteristics and traffic requirements of a smart grid communications network", Computer Networks, Vol. 57 pp-825–845. 2013*

iv. *IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems - Local and Metropolitan Area Networks - Specific Requirement Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs). (n.d.). doi:10.1109/ieeestd.2007.4299496*

v. *Murat Kuzlu , Manisa Pipattanasomporn, Saifur Rahman, "Communication network requirements for major smart grid applications in HAN, NAN and WAN", Computer Networks , Vol. 67, pp. 74–88, 2014*

vi. *Ancillotti, E., Bruno, R., & Conti, M. (2013). The role of communication systems in smart grids: Architectures, technical solutions and research challenges. Computer Communications, 36(17-18), 1665-1697. doi:10.1016/j.comcom.2013.09.004*

vii. *D. Locke, MQ telemetry transport (mqtt) v3. 1 protocol specification, IBM developer Works Technical Library, IBM, 2010 http://www.ibm.com/developerworks/webservices/library/wsmqtt/index.html*

viii. *Bormann, C.; Castellani, A.P.; Shelby, Z., "CoAP: An Application Protocol for Billions of Tiny Internet Nodes," Internet Computing, IEEE , vol.16, no.2, pp.62,67, March-April 2012 doi: 10.1109/MIC.2012.29*

ix. *D. Thangavel, M. Xiaoping, A. Valera, T. Hwee-Xian, C.K.Y. Tan, "Performance evaluation of MQTT and CoAP via a common middleware" IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Singapore, 2014, pp. 1–6. http://dx.doi.org/10.1109/ ISSNIP.2014.6827678*

x. *N. De Caro, W. Colitti, K. Steenhaut, G. Mangino, G. Reali, "Comparison of two lightweight protocols for smartphone-based sensing," IEEE 20th Symposium on Communications and Vehicular Technology in the Benelux (SCVT), 2013, pp. 1–6. http://dx.doi.org/10.1109/SCVT.2013.6735994*