A First Look at AMI Traffic Patterns and Traffic Surge for Future Large Scale Smart Grid Deployments

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***Abstract*—IoT (Internet of Things) applications are deployed in China with strong market requirements. To research the key technologies for future large scale IoT deployment, especially the impacts of IoT traffic to traditional IP network and Data Center, in this paper, we analyzed IoT traffic patterns and verified them through evaluation. IoT traffic patterns with layered system architecture and parameters affecting traffic are discussed. The evaluation results show that traffic surge generated by synchronous IoT application traffic cause network congestion for network and outage of Data Center resources. The transport protocols and data encapsulation format affect the application performance. These potential problems should be further research on.**

Keywords-AMI; large scale; traffic pattern; traffic surge.

I. INTRODUCTION

Several types of IoT services are provided to industry and human life, such as smart metering, point of sale, fleet management, telemedicine, environment monitoring and control, home automation, and so on.

Compared to traditional ways of using IP network of human-centric web applications, IoT services are different. The services have less randomness. The sessions are triggered by predefined time or events; the packet series inside a session is also predefined by the program. Usually, the number of IoT devices is very large. Parallel data transmission puts extreme amount of load on individual nodes of networks. The number of IoT devices is changeable. The data might be transmitted synchronously or with a random time schedule.

From the session level point of view, there are 3 cases [1]: The first case is periodical sessions. This is the case in environments monitoring service; the device reports the monitoring data every hundreds of seconds. In the second case, the session initiation times are random. This can be found in a point of sale service; a session is initiated once when people come to trigger a new transaction, not at predefined time. In the third case, the session is usually initiated periodically but may also be triggered by random events. This is the case in telemedicine services, when the physical characteristics data are sent every few minutes and an alarm is sent to the server once a monitored indicator is over or under threshold.

In the near future, massive IoT devices will be distributed everywhere with large scale deployment. Different types of sensors are used for different kinds of applications. IoT service will converge with human centric web applications. It will make a great impact on network and Data Center. New IoT service features generate new IoT traffic features. New IoT traffic patterns are also emerging.

In this paper, we determine three important IoT traffic patterns and analyze their potential problems. The following sections of this paper are organized as follows. In Section II, we analyze the IoT traffic patterns. Section III describes the study of IoT traffic surge, and perspective analysis for use case deployment. Section IV exposes the experimental process and the results. Finally, Section V gives the conclusion.

II. TRAFFIC PATTERNS ANALYSIS

A. *IoT Service Model*

Figure 1 shows the typical architecture of IoT system and the corresponding traffic. Data from sensor/meter is gathered through IP network, and transported to servers in data center. The accumulated traffic in data center can reach GB/TB level for computing, storage and networking process.

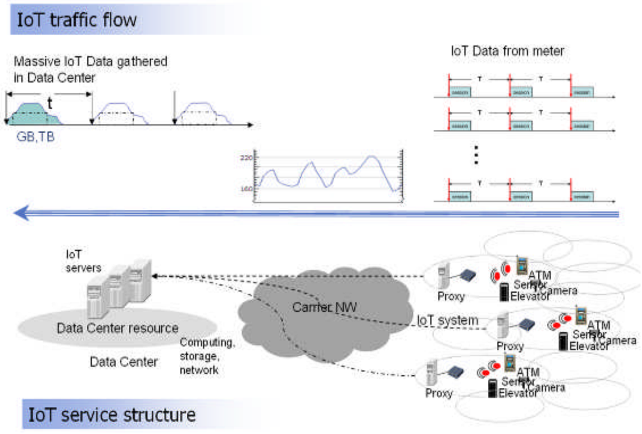


Figure 1. Architecture of IoT system and traffic.

B. IoT Numerical Model

We have several assumptions in the dedicated IoT service: sensors' gateways perform data aggregation and processing of sensor data before forwarding it to remote users. Data delivery models, event-driven, query-driven and periodic are assumed to be used by the gateways to transfer data.

We found the IoT traffic gathered in the Data Center server can be formulated as shown in Figure 2. The assumption is on base of IoT application parameters [2][3]. F is the frequency of meter data in sensor/meter. P is the packet sizes of the meter data. F'(t) is the time schedule of concentrator. S is the deployment scale level: like building deployment, site deployment or city level deployment.

$$f_{(F,\, P,\, T,\, S)} = \int^{S} \left(F^{*}\, P \,/\, f'(T) \right)$$

F: frequency of meter data, spans periods of 15s to 3 hours
P: packet sizes, ranging from 50 bytes to few MB
f'(T): time schedule of concentrator transmit
S: scale, Building/site, City

Figure 2. IoT Traffic model.

The IoT traffic has a hybrid traffic patterns. The following three models are selected for further research:

- Traffic pattern 1: Periodical traffic. Frequency: Real-time/Periodical: 15min, 30min, 45min. And Packet length: 50-300B/meter, MB/sensor, Use case: control and automation, transportation, environmental monitoring for emergency services and healthcare.
- Traffic pattern 2: Sessional traffic surge/burst, event-driven, query-driven, Frequency: 1h~1d~1M/Packet length: KB~MB, Use case: emergency report, booting
- Traffic pattern 3: Periodical traffic surge. In large scale deployment, the traffic load rises to the system resource capacity (threshold), or even over the system resource capacity (threshold). The hybrid traffic of Traffic pattern 1 and Traffic pattern 2 can generate periodical traffic surge, Use case: interactive, conversational, streaming.

C. IoT Traffic patterns with Layered Structure

Hybrid IoT traffic gathered in the Data Center, with the key parameters of: F, P, T, S. The total system has a layered structure. Layer 1 is the sensor/meter network layer, where real-time traffic is generated. Most of the traffic from layer 1 will go through GW/concentrator layer for a further time schedule. Some IoT traffic will go directly to layer 3. Layer 3 is the IP network, connecting large scale geography area. The hybrid IoT traffic finally reaches servers in Data Center: layer 4.

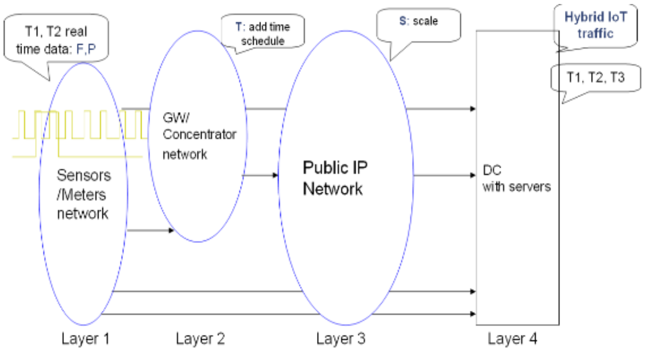


Figure 3. Layered structure.

Data collection frequency F and system scale S are parameters affecting total data volume. In a critical scenario, if the data collection frequency F is high, and the system scale S increases to a large value, the total data volume will be large.

The collection period (T1) and the collection time (T2) are parameters affecting the traffic shape. As shown in Figure 4 below, the predefined IoT traffic is periodically reporting data with T1 slot. The real transmission of the data in T1 slot is in T2 period. With different ratio of T1 and T2, the IoT traffic will be deferent.

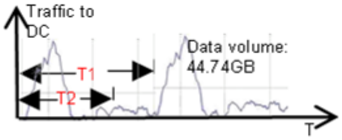


Figure 4. Collection period T1 and collection time T2.

III. TRAFFIC SURGES ANALYSIS

Periodical load surge from IoT application or special events (e.g., emergency alerting) will conflict with Data Center resource capacity, even inducing break down of Data Center systems.

A. Use Case Study

Mobile data traffic surge is expected to be 40 Exabyte by 2014 [4]. Mobile connections are expanding globally, along with other mobile connections, due to the growing hardware and software components for smart meters, business and consumer surveillance, inventory management, and fleet management, all of which are designed for operational excellence. Machine-to-Machine Traffic is expected to increase 40-Fold between 2010 and 2015.

Mobile carriers such as NTT DoCoMo, Verizon met mobile traffic burst, conflict with system resource. ISP like TAOBAO met traffic surge also. Its SecKill service, which is a kind of time-limited sales promotions, one web has requirements of 1billion in 10mins. The first system break down happened in 2009.

Chinese carriers/vendors are considering traffic/flow control. In carrier network, the real time large traffic is out of control. A possible solution might be an intelligent pipe:

broadband rapid respond for bandwidth requirements, resource allocation, optimization, and so on.

B. Beijng City Perspective AMI deployments

City level deployment of Advanced Metering Infrastructure (AMI) services is very popular in China. Table 1 shows the deployments in three cities.

TABLE I. AMI DEPLOYMENT BY 2011

City	L2 devices (GW/Concentrator)	User Number
TaCheng, XINJIANG	36000smart meter, 185 collector	19,200
LuCheng, Wenzhou, ZHEJIANG	14,485 cellular collector	190,405
HuZhou, ZHEJIANG	487.1 thousand cellular/microwave collector	HV 12690， LV 1187,700

Refer to the AMI deployment of HUZHOU in 2011 [5], with the population result of 2010; we can get the forecast AMI numbers of BeiJing for city level deployment shown in Table 2.

TABLE II. PREDICTIVE NUMBER FOR BEIJING DEPLOYMENT

	BeiJing	HuZhou
Population	19.612 million	19,200
People/House density	2.45	2.65
House Users	8,000,000 users	1200,000 users
L2 devices	3,600,000 collector	487,100 collector

Table 3 is the comparison of China railway public ticket ordering system 'www.12306.cn' [6] and AMI service. The ticketing system met heavy traffic surges especially at spring festival ticket release time. At 8, 10, 12, 15 everyday the traffic surges happened. As the deployment reaches a large scale, and the interactive requirements increase, AMI applications have a high possibility to have traffic surges periodically as well.

TABLE III. TRAFFIC SURGE POSSIBILITY

	12306	AMI
Parallel traffic	1GB	< 1GB
Server load	1GB	MB level
User number (peak)	5 million, KB/user	5 million, KB/user
mode	interactive	Light interactive

The common solution is to increase the system capacity. But, there are some solutions considering IoT traffic surge [7][8][9][10]. Like [11], in M2M communication: terminal self-test and determine communication gap to avoid traffic congestion. Or, some vendor has a hardware solution of DC network IF with huge size buffer.

IV. EVALUATION RESULTS

We use AMI as the example for evaluation of IoT traffic patterns, its impacts and problems. The AMI system will be deployed in large scale [12]. Thus, the application will generate massive AMI data [13]. This massive AMI data will be transported through IP network and processed in the data center.

A. Platform Implementation

We select AMI Beijing city level deployment as the application scenario as shown in Figure 5. Sensors' data is collected every 15min 60Byte/meter, periodical data delivery (transmission finished within) in network. Traffic Generator send IoT traffic: historical AMI data repeating, predicted AMI data, AMI data through mathematics model. Multiple Traffic Generators simulated massive IoT traffic to IoT server in Data Center virtualization platform. Evaluation parameters: traffic model to Data Center, capacity, jitter, traffic/time model for different AMI scenarios.

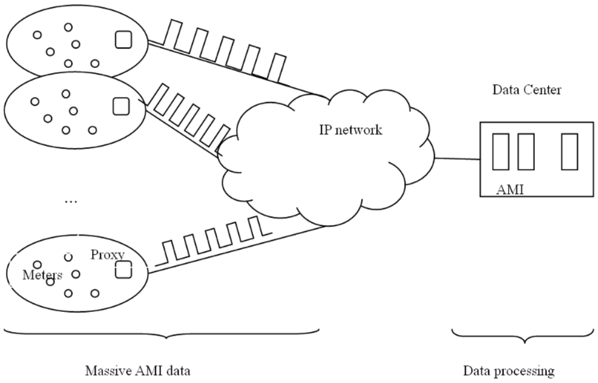


Figure 5. Logical System Structure.

In Figure 6, the Traffic Generator (TG) is used to generate massive AMI data. Multiple TGs are used to simulate distributed AMI systems. Data from TG will be transmitted to IP network, through local or public network. The AMI server and database are in the data center, with virtualization platform.

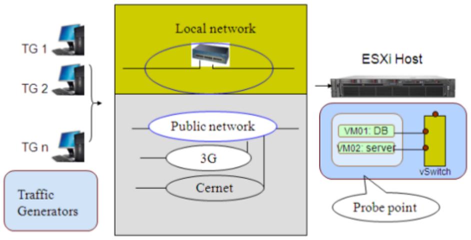


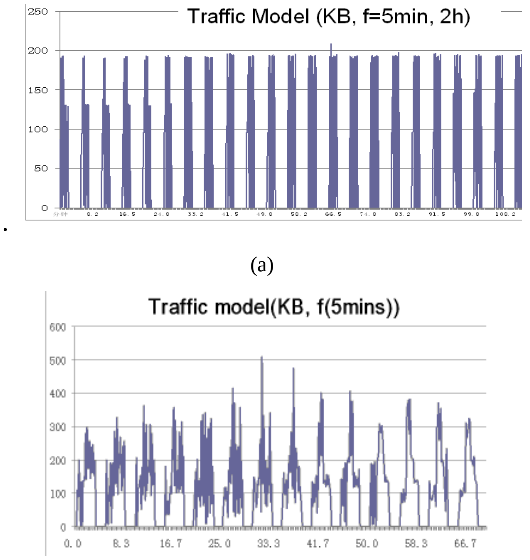
Figure 6. Evaluation System structure.

B. Problem Analysis

a) Traffic Paterenss via Evaluation

Traffic patterns are monitored through evaluation.

Data from sensors, through the public IP network, is gathered in the AMI server. The traffic is shown in Figure 7 below. It is periodical traffic. In Figure 7(a), it is around 6000 sensor's metadata, through 24 concentrators, sending data to servers in data center. The data frequency is set to 5 minutes, for it is easier to get the test result than 15 minutes used in the commercial system.



(a)

(b)

Figure 7. Layered structure.

In Figure 7(b), we increased the number of the sensors to 18000, through 72 concentrators. The total traffic arriving at the server in data center is shown in Figure 7(b). Compared to the result in Figure 7(a), the traffic in one period is affected with jitters. However, the periodical feature is still not changed. And the traffic in every period has similar traffic model features from statistics points.

b) Traffic Impacts to Data Center

Corresponding to the traffic patterns in Figure 7(a) and 7(b), the CPU and memory utilization in data center servers is pushed to have the same periodical load model feature.

Potential problems:

(1) Low efficiency: in the time slots between the transmission periods, IoT dedicated resources like computing, storage and network are in low efficiency status.

(2) Resource Bottleneck: For large scale massive data generated traffic surge, during the session, the allocated resource will be bottleneck to the load.

c) Traffic Impacts to network

Network resource occupation competition:

In the concentrator, there are long packets series transmitted in a short period; it occupied the network I/O buffer. In the server, packets from concentrators have competitions for the network resources. Especially in wireless network, the wireless buffer and channel resource are limited. Figure 8 shows a delay burst in the wireless channel while the wireless channel is rather congested.

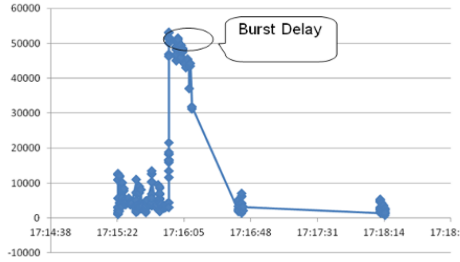


Figure 8. Delay in wireless channel competetion.

Potential problem:

(1) Long packets series, with synchronized feature for real-time applications, will generate network congestion. Then the application quality will be affected.

d) Traffic Impacts to applications QoS

The traffic model has an impact on application QoS parameters.

As Figure 9 shows, the TG sends 6000 sensor's data. These sensor's data are encapsulated in XML format and transported over TCP/IP. In one sending period, one stream, around 4KB, are divided into packet series to the TCP receiver in the server, and the server will buffer these packets, until the last packet comes. Then these 4KB data will decapsulated together. So the delay of the data in the first packet is increased with the longest buffering time: the delay of the data in the last packet is the shortest one. If the number of the packets increases together with sensor number, this factor will affect the application QoS more deeply.

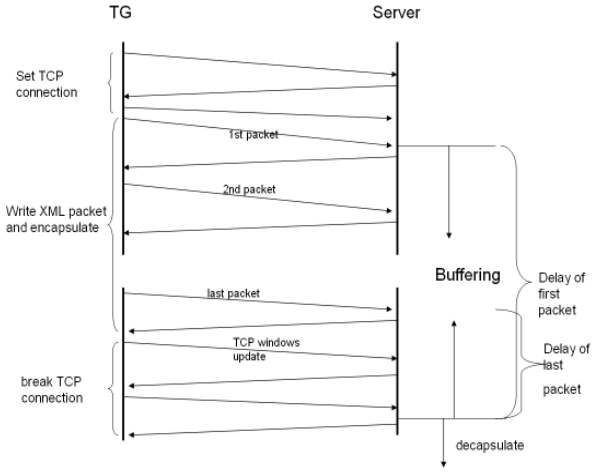
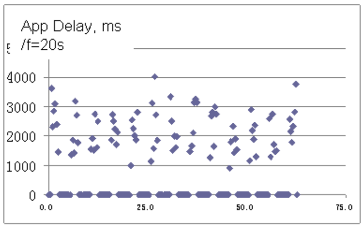


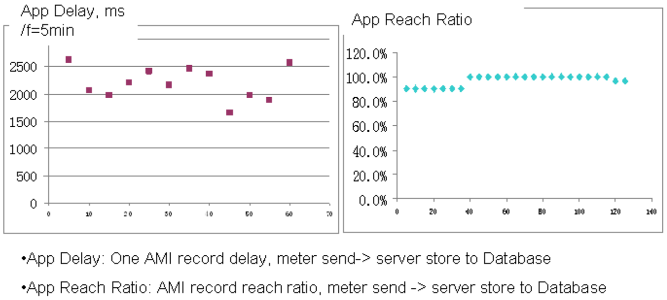
Figure 9. TG + Server schedule.

Figure 10 is result of the application QoS. They are sensor meta data delay average in 20 seconds (a), sensor meta data delay in 5 minutes (b), and sensor meta data reach ratio(c). In

Figure 10, 6000 sensor's data cross fixed public IP network, has average delay in seconds level.



(a)



•App Delay: One AMI record delay, meter send-> server store to Database

•App Reach Ratio: AMI record reach ratio, meter send -> server store to Database

(b) (c)

Figure 10. Application QoS Parameters.

Potential problems:

(1) How to decrease the delay in the application layer and assure the QoS of IoT services for this traffic model?

(2) Transportation protocols and data encapsulation format (packet length, format) are important parameters of the traffic model. For TCP transportation, with long packets series, uniform packets encapsulation, the application QoS will be decreased.

In the test bed, TCP was the protocol used for assuring packet transmission. However, depending on the network status, TCP windows update mechanism will result in delay and even packet loss. On the other hand, if we use UDP protocol, the delay of above problem can be solved to some extent. However, in channel or network congestion, there will definitely be packet loss of the sensor data.

We use XML format for the meta data in the test bed. This format is easier for encapsulation and decapsulation. However, the efficiency for transmission and server processing is not enough, especially for massive data from sensors. There also should be an efficient and standard meta data format.

V. CONCLUSION

Large scale IoT deployments generate a new class of traffic. It is important to know the large scale IoT deployments impact on Data Center and the network. Potential problems should be further studied. These include: traffic surge generated by synchronous IoT application, in which traffic may cause network congestion and outage of DC resources. In this report, we discussed the IoT traffic modeling and evaluation in order to clarify the impact of future large scale IoT server on network and data center. Through the IoT traffic modeling analysis and the evaluation work, we found the potential impacts and problems of IoT massive data to datacenter, network and application QoS.

Traffic surge generated by synchronous IoT application traffic may cause network congestion for cellular network and outage of DC resources. The transport protocols and data encapsulation format will affect the application processing performance greatly and should be carefully selected. It is important to find solutions to these issues.

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