Performance Evaluation of M2M and H2H Communication Coexistence in Shared LTE: A DLMS/COSEM-Based AMI Network Scenario

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1 Introduction

A typical architecture of an AMI network is shown in Fig. 1, which is composed of three main blocks: (1) the local data collection units, (2) the communications network, and (3) the management and control center, the energy company. According to Fig. 1, communication networks constitute the "backbone" of an AMI architecture in which AMI is the core device and acts as a gateway between Home Area Network (HAN) and Neighborhood Area Network (NAN).

With the rapid deployment of smart meters into the AMI networks; M2M in LTE, relying on cellular networks imposes overload issues, the network congestion, increases delays, packet loss, and even causes service interruptions [2].

In this paper, we investigate on the performance of LTE communications for smart meter traffic, in the presence of LTE background traffic such as VoIP, HTTP browsing, FTP, video streaming, and gaming. We assume a public, shared LTE network for data transfer; therefore, the amount of background traffic has a big impact on the latency of the smart metering traffic and background Internet traffic. A series of experiments were conducted with the increase in number smart meters and LTE background traffic applications to verify the quality requirements as specified in [3]. The performance metrics for LTE such as throughput, packet loss ratio, and point-to-point (P2P) delay are investigated using network simulator version 3.

The remainder of the paper is organized as follows: In Sect. 2, we describe the related work in the literature followed by AMI component models and LTE Internet traffic models implementations in NS-3. In Sect. 4, the results obtained from these simulation experiments are presented, followed by implications of the findings and future work.

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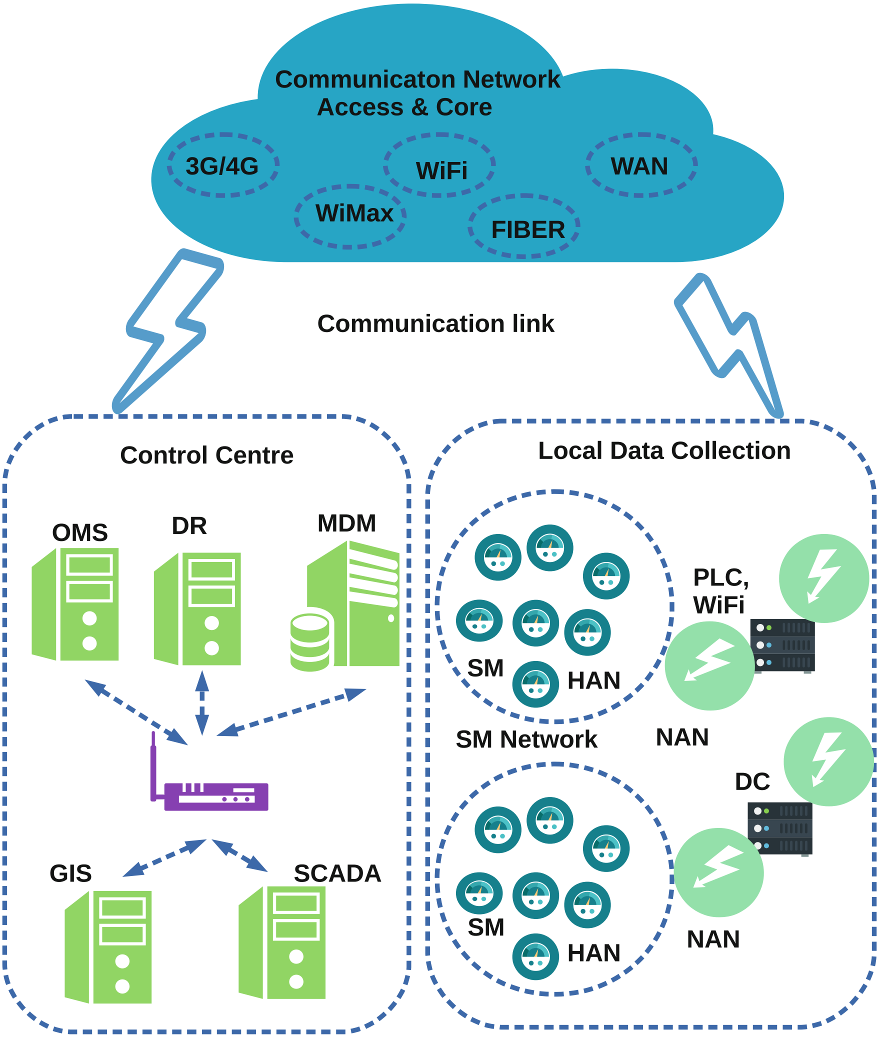

Fig. 1. Architecture of an AMI network [1]

2 Related Work

Reviewing the literature on the subject, we found similar works focusing on the evaluation of the performance of communication schemes and protocols for measurement reading networks or AMR (automated meter reading)/AMI implemented on the communication technologies through PLC (power line communication) [4], cellular [5], and the DMLS/COSEM protocol. In [6] the performance of ZigBee, LTE, and WiFi under different sizes, node layouts, and different transmission sequences is investigated to compare the maximum distance for transmitting data between DCU and AMI devices under log-distance channel propagation of three wireless technologies. In machine-to-machine (M2M) networks, a scheme is proposed in [7] which dynamically partitions and allocates the random access channel (RACH) resource to overcome the overload problem caused by random access requests from massive M2M devices defined by the Third Generation Partnership Project (3GPP).

To improve the accuracy of routine that simulates the LTE random access channel (RACH) was proposed in [8], which was subsequently used in our work to assure the QOS requirements are satisfied for the video services. So authors have realized that so far, there was no real attempt has been made to study the impact of background traffic on the performance of smart meter functions and vice versa, especially in public, shared LTE networks. Therefore, present work is an attempt to evaluate the mutual impacts between smart meter traffic and background Internet traffic, and is aimed at network/mobile operators who want to know the impact of AMI traffic through cellular communications infrastructure especially in the presence of existing background Internet traffic.

3 AMI Component Models in NS-3

The basic COSEM model proposed by Juan M. Aranda [9] for an intelligent electric meter with total active energy (kWh) Extended register was used. All smart meters (Fig. 2) work behind the DCs, so we have created WiFi links with the help of WifiHelper and lower layers are configured with the help of YansWifiPhyHelper and NqosWifiMacHelper. As shown in Fig. 2, the LTE stack is also installed on the DC that allows it to connect to the MDM to relay (route) the traffic of the smart meters from the WiFi link. The MDM host is implemented as a node connecting to the P-GW of LTE network through a point-to-point link

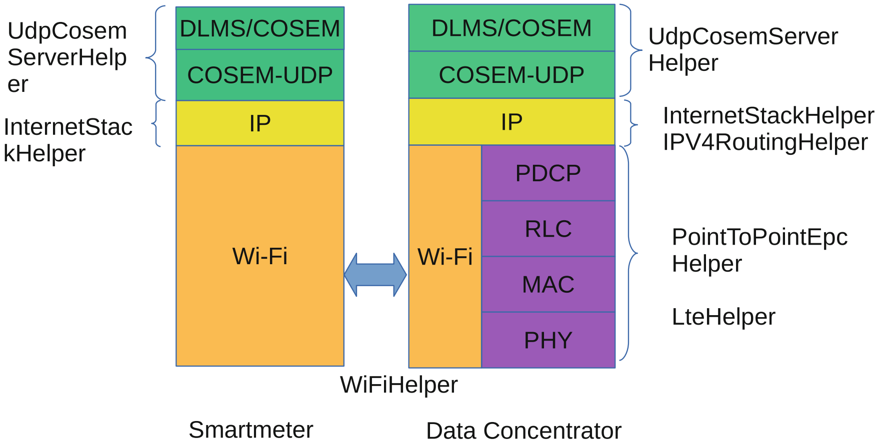

Fig. 2. Implementation of the WiFi smart meter and WiFi/LTE DC in NS-3

(using PointToPointHelper). At the application level, meter data management (MDM) system has the functionality intended for the management of meter reading data. Similar to the SM and MDM node implementations, the background UEs have LTE network interface, IP stack, and LTE stack installed. After that, different applications mentioned in Table 1 are installed on the nodes with the help of GeneralUdpServerHelper [10]. A CSMA network is implemented with MDM host and remote hosts of different traffic types using C++ classes CsmaHelper and GeneralUdpClientHelper.

Table 1. Background traffic mix

Application	Traffic	% users
VOIP	Real-time	30
FTP	Best effort	10
HTTP	Interactive	20
VIDEO	Streaming	20
GAMING	Interactive real-time	20

4 Experiments and Evaluation

4.1 The Simulation Scenario in NS-3

The simulation scenario as shown in Fig. 3 was proposed to evaluate and analyze the performance of communications for an AMI network.

The simulation experiments run on NS-3 version 3.26 and Ubuntu 16.04 LTS. Simulation experiment assumes point-to-point connection between S-GW/P-GW and remote hosts (including MDM). Simulation parameters defined by [11]

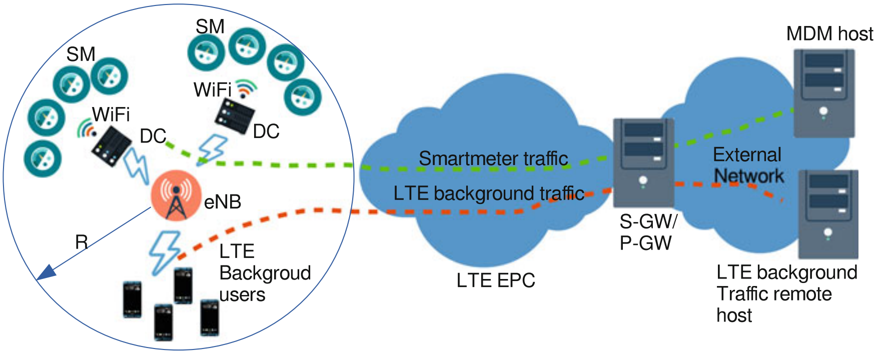

Fig. 3. Single cell simulation topology

Table 2. Simulation parameters

Parameters	Values
Uplink bandwidth	5 MHz
Downlink bandwidth	5 MHz
Transmission mode	MIMO 2 × 2
UE transmission power	26 dBm
eNB transmission power	49 dBm
Cell radius(R)	800 m
Simulation time	2000 s
No of eNB	1
No of DC	5
DC polling time	1 min
MDM request to DC	3 min

were used in the experiments and are shown in Table 2. The proposed scenario consists of the following:

- Five local networks of smart meters (SMs), belonging to a low voltage distribution network, managed by data concentrators (DCs).
- Five DCs with a capacity of up to 1,000 SMs distributed over an urban area (mostly residential and commercial) and with the ability to execute polling mechanisms to request the measurements from SMs every 60 s.
- A single cell of radius R is configured with the models and parameters of Table 2. It has the ability to simultaneously service the DCs and several fixed users that demand Internet applications.
- A metropolitan network implemented over optical fiber, capable of transporting the traffic generated by SMs and remote hosts.
- Five remote hosts (VOIP, HTTP, FTP, video streaming, and gaming) and the smart grid control center (MDM) are connected to a router. The control center (MDM) runs the RequestingAPP application, which is responsible for requesting and receiving DC data every 180 s.

4.2 Simulation Results and Analysis

This section presents the simulation results and analysis for the conducted experiments. All plots were drawn using GNU Octave, version 4.0.0. Three different cases for simulation were considered.

Fixed Background Traffic and Variable AMI Traffic Clearly, it can be seen in Fig. 4 that both the average throughput and the average point-to-point

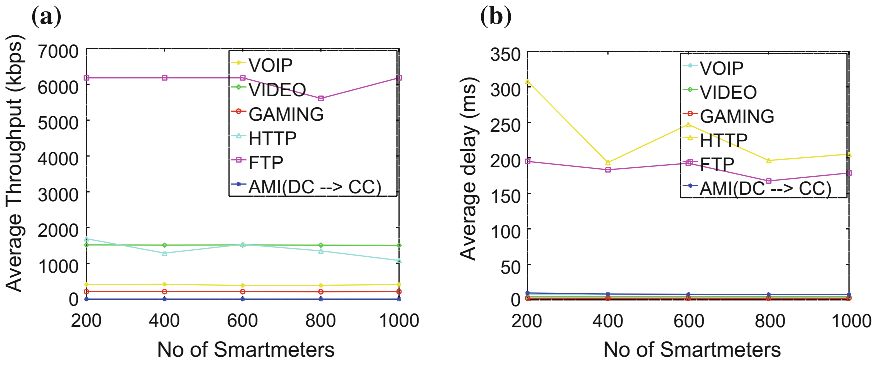

Fig. 4. Performance metrics per application with fixed (100 users) background nodes. **a** Throughput and **b** point-to-point delay

delay per application are kept practically constant in the face of the increase in the number of SMs per network.

With respect to the AMI traffic through the LTE network, it is observed that the average throughput in the DC and control center (DC -> CC) direction increases as the number of SMs increases.

On the other hand, the total average AMI delay (Fig. 5a), i.e., the time spent from the moment the request is issued by the control center until later receives the data transferred by the DC, is 10.79 ms, during which time an average of 7.75 Kb was transferred for each request made by the CC (for a total of 1,000 SMs per DC) (Fig. 5b). This delay is below the limit established by the QoS (Table 3). The packet loss ratio (PLR)for different applications including AMI (Fig. 5c) is constant with increase in number of smart meters and offers a high reliability for all applications. Therefore, under this scheme, a high percentage of coverage is achieved without overloading the network and guarantees the quality of the services offered. This fact may motivate telephone operators to offer their telecommunications infrastructure services to AMI network operations without much infrastructural changes.

Fixed AMI Traffic and Variable Background Traffic Figure 6 shows the simulation results obtained for different traffic loads of mobile Internet applications. Clearly, performance metrics for video applications were deteriorated as traffic increases within the cell, and a point was reached where it is no longer possible to guarantee the quality requirements for the video service. With 150 users within the cell, an average point-to-point delay of more than 250 ms was observed, i.e., the QoS requirement was not satisfied (Table 3) and a percentage of received packets of 98%, i.e., reliability of packet transfer was reduced by 5.88% compared to the confidence obtained in the previous scenario (Fig. 5c). Additionally, the total average AMI delay was increased to 10.85 ms (5% increase). Therefore, by not guaranteeing the quality of service (QoS) requirements of the

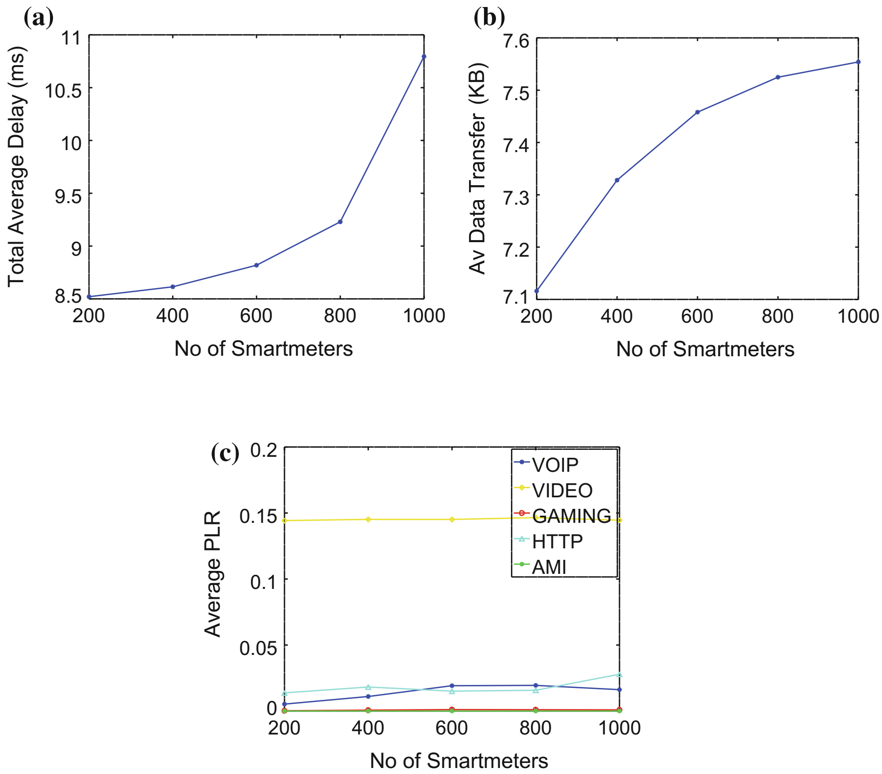

Fig. 5. Average total delay, AMI data transferred to the CC, and packet loss ratio with fixed (100 users) background nodes. **a** Average total delay, **b** Av total AMI data transferred, and **c** packet loss ratio (PLR)

video application, it is no longer possible to continue servicing more than 150 background users and 5000 SMs (1000 SMs per DC).

Table 3. Quality requirements for the applications offered [3]

Application/Parameter	VOIP	VIDEO	HTTP	FTP	AMI
End-to-end delay	<150 ms	<250 ms	<400 ms	No limit	<15 s
PLR	<0.01	<0.1	<0.001	<0.001	<0.001
Jitter	<50 ms	<2 s	N.A	No limit	N.A

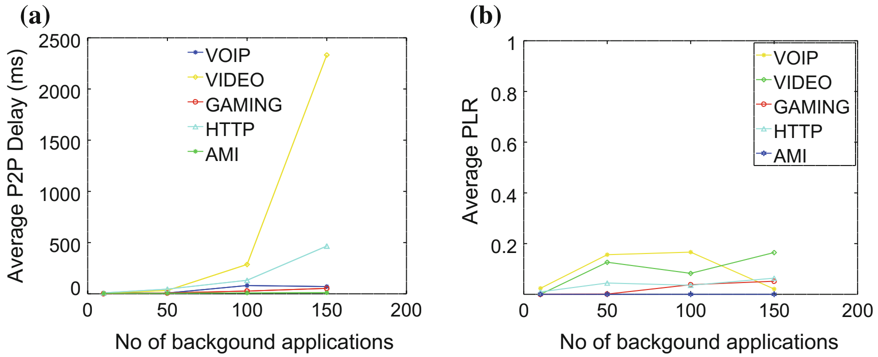

Fig. 6. Average total delay and PLR for fixed (150 users) background nodes. **a** Average total delay and **b** packet loss ratio

RACH for Fixed AMI Traffic and Variable Background Traffic An NS-3 patch implemented by Michele Polese [8,12] was used to demonstrate the LTE RACH for evaluating the background traffic with fixed AMI traffic.

Clearly, the average P2P delay of 120.0741 ms (Fig. 7a) for video application was reduced by large amount and is well within the QOS requirements (Table 3). From Fig. 7b, AMI total delay (11.2514 ms) is also within QOS requirements.

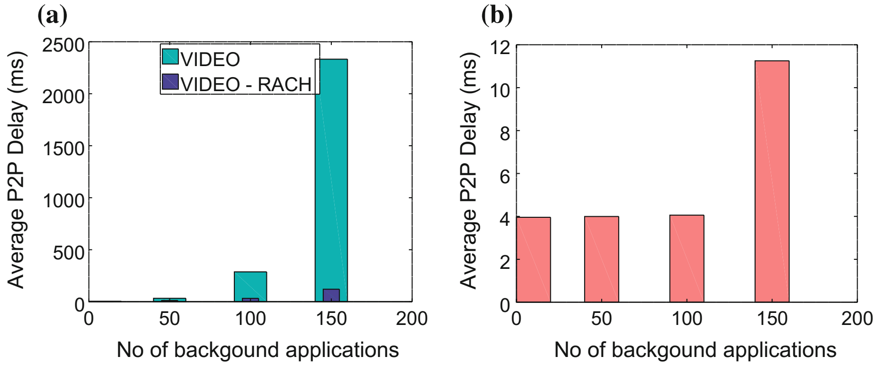

Fig. 7. Average delays for video and AMI applications using LTE RACH. **a** Average P2P delay comparison for video applications and **b** average total delay for AMI

5 Conclusions

This paper presents the results of performance evaluation of a communication scheme for an AMI network as well as H2H applications when they coexist inside a public, shared LTE network using the NS-3 network simulator. The scenarios with large numbers of simultaneous Internet users (along with 1000 SMs per DC) within the cell (up to 150), it was observed that the quality requirements of the video services (streaming) were affected. An LTE RACH procedure has been successfully demonstrated to restore the same. The authors have uploaded the entire NS-3 source code of the simulation experiments including Octave scripts for plotting to Github, a global supporting community for developers.[1]

5.1 Future Work

As a future work, it is proposed to carry out the simulation experiments using 6LowPAN and LR-WPAN in NS-3 for AMI networks.

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