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Providing Network Time Protocol Based Timing for Smart Grid Measurement and Control Devices in 5G Networks

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Abstract— Smart grids are key enablers for creating sustainable energy systems. On the other hand, they introduce a grid management challenge as power grids become more complex and dynamic. Evolving power grids towards smart grids requires combining electric energy technology with communications and information technology. In a distributed network, time synchronization is often one central question. This paper studies limitations of utilizing the widely used Network Time Protocol (NTP) in current 4G cellular networks for smart grid management. As a specific contribution, an improved, NTP based clock adjustment algorithm is proposed to provide more accurate timing information. Finally, the paper studies capabilities of emerging 5G cellular networks to further improve accuracy of timing provided to user equipment (UE).

Keywords—NTP, 4G, 5G, URLLC, Smart Grids, Fault Location, Asymmetric networks.

I. INTRODUCTION

Smart grids are key enablers for creating sustainable energy systems. On the other hand, they are huge, highly distributed, dynamic networks. This introduces a network management challenge. Information and communications technologies will be extensively used to address this challenge.

The current cellular networks facilitate the possibility of adding new smart grid control and measurement points like fault location devices to quickly anticipate, mitigate and detect fault situations. In order to effectively utilize these new devices, accurate, reliable, and cost-effective time synchronisation is required to align current and voltage measurements coming from the numerous devices in the distributed grid.

This paper first studies the limitations of Network Time Protocol over the current 3GPP 4G/LTE cellular networks to provide timing for smart grid control and monitoring. Then, as a specific contribution, an improved NTP clock adjustment algorithm is proposed. Thereafter, the emerging cellular 5G networks are analysed to overcome the limitations of 4G/LTE cellular networks.

The rest of the paper is structured as follows. Section II provides background by giving an introduction to smart grid challenges. It analyses how providing accurate timing using NTP over cellular networks could help in addressing them. Section III discusses NTP and its challenges. Section IV continues by evaluating NTP performance in a 4G/LTE (Long Term Evolution) cellular network having some 5G features. Section V introduces an improved adjustment algorithm for NTP in 4G/LTE networks and evaluates its performance. Thereafter, Section VI discusses upcoming 5G capabilities potentially improving NTP performance and the performance of the proposed adjustment algorithm. Finally, Section VII provides a summary and conclusions, and discusses options for future work.

II. SMART GRID CHALLENGES

Smart grids enable extensive integration of distributed generation based on renewable energy sources like solar and wind. They engage consumers as active players for maintaining power balance and improving efficiency e.g. through demand response solutions. Some of the consumers become also small-scale producers of electricity, e.g. by selling electricity produced by solar panels mounted on roofs of residential buildings, or discharged from electric vehicle (EV) batteries, when electricity price is lucrative.

On the other hand, smart grids increase network management complexity. The number of generation units will proliferate. Instead of a relatively small number of big generation units, e.g. hydro or nuclear power plants, smart grids will also include great number of small generation units. These small units are scattered all over the distribution grid. Thus, the whole power grid topology changes from being a top-down network into a meshed network. Furthermore, these new, small generation units are in most cases fundamentally intermittent as their generation capabilities depend on momentary weather conditions.

An essentially greater number of managed devices, a new network topology principle, and increased dynamics and unpredictability are challenges to any network management system. In case of smart grids, they also introduce phenomena like bi-directional and weaker fault currents, making

protection and fault location more difficult, and challenges in maintaining the continuous balance between the supply and the demand.

To address the challenges smart grids will extensively utilize information technologies and communications networks. Smart grids will include a rapidly increasing number of active measurement points and control devices. These distributed devices are connected to network management information systems by communications networks, e.g cellular networks.

In many cases these devices need to be time synchronized to align measurements which are being done continuously, but delivered to the central or cloud based data repositories only periodically or sporadically. Deliveries can take place as requested e.g. by a SCADA (Supervisory Control And Data Acquisition) system, or unsolicited in case of abnormal or suspicious measurement values. Applications like monitoring temperatures and vibrations of transformers and other smart grid assets, do not require very high timing accuracy. But for some applications, like distributed fault location [1], a sub-millisecond level timing would be preferable. In a 50 Hz network having fundamental period of 20 ms timing misalignment of 0,1ms corresponds to 1,8 degrees in voltage or current values. This gives a best-case error of about 0,05%. Correspondingly, a misalignment of 1 ms corresponds to 18 degrees in voltage or current values. This gives a best case error of about 5 %. In case of fault location of single-line-to-earth faults, it should be noted that the resulting discharge transient has typically a duration of less than 60ms with emphasis on the first 10 ms [2],[3]. If only millisecond level timing is available, further alignment of voltage and current measurements coming from different devices could be done by utilizing fundamental frequency waveforms derived by lowpass filtering.

The cost of the measurement and control devices should be minimized. Thus GPS (Global Positioning System) should preferably be avoided. On the other hand, as the devices are part of the smart grid, they in many cases can have a constant power supply from the grid and only a smaller backup battery.

This paper studies capabilities of popular Network Timing Protocol (NTP) and emerging 5G cellular networks to provide timing for smart grid monitoring and control devices.

III. NETWORK TIME PROTOCOL (NTP) CHALLENGES

Network Time Protocol [4] is a widely used protocol for distributing timing in fixed networks. In a typical fixed local area network it achieves a one millisecond level timing accuracy [5]. NTP uses advanced algorithms and statistical methods to avoid abrupt time stamps and to enable smooth client clock adjustments. Simple Network Time Transfer Protocol (SNTP) [6] is a simplified version of NTP for applications where requirements for accuracy are not too demanding. Another, but also weaker time synchronization mechanism for mobile devices is Network Time Identity and Time Zone protocol (NITZ) [7]. It could also be noted that although layer 1 in cellular networks typically requires very accurate timing, this timing is not available to applications on the UEs.

NTP is based on exchanging UDP (User Datagram Protocol) messages containing time stamps. The packet arriving to the NTP client includes three time stamps $t1$, $t2$,

and $t3$. $t1$ is the time (according to the client clock) when the client sent a packet to the NTP server and $t2$ is the time (according to the server clock) when the NTP server received it. $t3$ is the time when the NTP server sent the response packet to the client. NTP client also logs the fourth time stamp, $t4$, which is the arrival time of the response packet. NTP client calculates (1) the latency from the server to the client, $t_latency_s_to_c$, by first calculating the roundtrip time ($t4-t1$), subtracting server processing time ($t3-t2$) and then dividing the result by two. The division by two means that NTP client assumes that the latency (delay) from the client to the server, and the latency from the server to the client are equal.

$$t_latency_s_to_c = ((t4-t1)-(t3-t2))/2 \quad (1)$$

Offset in NTP represents the amount to adjust the local clock to align it with the reference clock in the server. Thus, if the offset is positive, client's clock is behind the server's clock and vice versa. NTP client calculates (2) the offset, t_offset by subtracting its time, $t4$, from the correct time. The correct time is derived by adding latency from the server to the client, $t_latency_s_to_c$, to the time in the server $t3$.

$$t_offset = t3 + t_latency_s_to_c - t4 \quad (2)$$

As said, the fundamental assumption in NTP is that latencies from the client to the server and from the server to the client are equal. If this is not the case, the error in offset will be half of the difference between these two latencies based on (1) and (2).

Varying and asymmetric latencies are the clearly dominating cause for errors in NTP based timing. Other, much smaller error sources, are client instability, asymmetry in network interface cards, and server instability [5].

IV. NTP PERFORMANCE IN 4G/LTE CELLULAR NETWORKS

This section describes the testbed setup used to measure the performance of NTP to provide timing information for the smart grid measurement and control devices. The results from the testbed are presented in this section to highlight the current limitations of NTP in 4G cellular networks.

A. NTP testbed setup

The NTP testbed consists of a real deployment of 4G/LTE cellular network. It utilizes nation-wide 5G Test Network Finland (5GTNF) and the 5G test network implemented in Espoo, Finland.

The testbed consists of the following components:

- Nokia Flexi Zone Indoor Pico BTS 4G base station (eNodeB)
- 5GC, 5G Core Network [8] like core (hereinafter the 5GC core) running on Ubuntu 16.04.5 on PC Engines apu2 system board
- HP 14-bw0xx laptop (hereinafter the client device or User Equipment, UE), running Ubuntu 16.04.5, and an attached Huawei E3372 4G/LTE USB modem (dongle). These emulate a smart grid measurement and control device.

- NTP keeps laptop (UE) clock accurate by a connection to an GPS locked NTP server (Trimble Thunderbolt GM 200 Grandmaster Clock) attached the same fixed LAN.
- To study the NTP performance in a 4G/LTE network, 5GC core runs a NTP server which delivers timing information over the 4G/LTE network to the laptop (UE). This is for comparison only so NTP client on the UE does not try to use it to adjust the clock. This is achieved by utilizing "noselect" option while configuring the timing source in ntp.conf file. The clock of the 5GC core NTP server is delivered from a Stratum-2 NTP server on the same fixed LAN.

Fig.1 shows the testbed components as well as the topology on how they are connected to measure the NTP performance. All components are located in the same room.

Fig. 1. Testbed components and topology

Fig. 2 shows the main software components of the 5GC core [8]. AMF, Access and Mobile Management function is in charge of UE authentication, authorization and connection management. SMF, Session Management Function, supports establishing, managing and releasing a user session. UPF, User Plane Function, supports forwarding of the user data between the UE and the counterpart, e.g. an internet based application.

Fig. 2 Main software components of the 5GC core

B. Evaluating NTP in 4G/LTE cellular networks

NTP's ntpq utility (ntpq -p command), running on the client device, was used to monitor NTP's performance. In Fig. 3 there is an excerpt of the test script output executing ntpq -p command once in about 50 seconds. Client's clock is correct to a sub-millisecond level as it is locked, to an

accurate NTP server in the same fixed LAN as indicated by the asterisk (*) in Fig. 3. On the second row, ntpq reports timing information received from the 5GC core (IP address 172.16.0.1) over the 4G/LTE radio link. "noselect" option has been defined for this timing source in the /ntp.conf -file. Thus, the information is just displayed as a reference and ntp daemon is not taking it into account when adjusting client's clock. It should be noted that delay in the ntpq -p output means roundtrip time from the NTP client to the NTP server and back.

Fri 1.2.2019 15.28.13 +0200	remote	refid	st	t	when	poll	reach	delay	offset	jitter
*192.168.1.250 .TBLT.			1	u	2	8	377	0.203	-0.002	0.038
172.16.0.1 172.16.0.10			2	u	6	8	377	33.189	9.359	0.163
Fri 1.2.2019 15.29.03 +0200	remote	refid	st	t	when	poll	reach	delay	offset	jitter
*192.168.1.250 .TBLT.			1	u	4	8	377	0.227	0.014	0.125
172.16.0.1 172.16.0.10			2	u	-	8	377	33.247	9.242	0.048
Fri 1.2.2019 15.29.53 +0200	remote	refid	st	t	when	poll	reach	delay	offset	jitter
*192.168.1.250 .TBLT.			1	u	6	8	377	0.252	-0.009	0.197
172.16.0.1 172.16.0.10			2	u	2	8	377	33.343	9.214	0.062

Fig. 3. NTP shows incorrectly an offset while running over a 4G/LTE channel

Table I summaries NTP performance measurements over a 4G/LTE connection during 9 calendar days is 6 separate measurement sessions. Total number of observations is 11643 and their interval about 50 seconds. As can be seen in both Fig. 3 and Table I, ntpq is constantly reporting an essential positive offset, in this case about 9 ms. This means that NTP states that client's clock is always behind even though this is not the case. This is what happens according to (1) and (2), if the latency from the server to the client is in reality always shorter than the latency from the client to the server. If the reported offset is say 10ms, the downlink latency (from the base station to the client device) is 20 ms shorter than the uplink latency. In the next section we will study further 4G/LTE radio channel characteristics and how they could be addressed to improve NTP performance.

TABLE I. NTP PERFORMANCE OVER A 4G/LTE CONNECTION DURING 9 CALENDAR DAYS

	Roundtrip (ms)	Offset (ms)
Median	33.13	9.33
Standard deviation	1.58	0.85
3rd quadrant	33.18	9.42
1st quadrant	33.07	9.23
Number of observations	11643	11643

V. IMPROVED NTP CLOCK ADJUSTMENT ALGORITHM FOR 4G/5G NETWORKS

A. 4G/LTE radio channel characteristics

There are studies on NTP performance in wireless environments (e.g. [7],[9],[10]) but based on our state of the art review 4G and 5G cellular networks characteristics have received less attention in this regard.

4G/LTE radio links are fundamentally asymmetrical [11],[12],[13],[14],[15]. The primary reason for this are resource allocation and scheduling mechanisms as UEs (User Equipment) have to request uplink transmission resources from the base station [11],[15]. According to [11], the median downlink latency is about 8 ms. In about 90 % of cases the downlink latency is between 5 and 13 ms, and it is fairly independent of packet size. On the other hand, the uplink has a median latency of about 29ms. In about 90% of the cases the uplink latency is between 15 and 35 ms, and it is also fairly independent of packet size. Thus the difference between uplink and downlink is about 21 ms (29-8). Reference [11] shows that latency in the 4G/LTE backhaul and core network is only about 1,5 ms, i.e. essentially less than uplink and downlink latencies in the radio channel. This observation is well in alignment with [14]. Furthermore, it should be noted that latencies in the core network can be maintained relatively symmetric and statistically stable by applying appropriate planning for switching and routing.

The results in [11] are in alignment with [12], [13] and [14]. In [13] the difference between uplink and downlink latencies is 32 ms and it is relatively independent of packet size. In [13] the opposite measurement point to the UE reside further away, so the overall delays are longer, for downlink about 47 ms and for uplink about 79 ms. In [14] the uplink delay in 4G/LTE radio interface is about 20 ms and downlink about 7 ms. Delay in the backhaul and core are only about 0,7 ms. In [12] the uplink latency in the 4G/LTE radio interface is 20-25 ms and in down link about 8-13ms. Interestingly, [12] also states that these figures remained stable while moving in areas with good coverage: “jitters stayed on a low level, being about 1ms and 3 ms downlink and uplink, respectively, in well covered areas.” Reference [12] reports another interesting observation which is that uplink latencies start to increase while downlink latencies remain fairly stable when moving to areas with poorer coverage. This is explained by the very low transmission power of UEs compared to base stations. Reference [12] states that there are sporadic spikes and losses, which is characteristic to radio channels, but apart from those the latencies reported above are typical.

Based on the above, it can be concluded that, depending on the particular UE and base station and their transmission power, there is, when observed over a longer period:

- an inherent asymmetry between uplink and downlink latencies in the radio interface, downlink being faster. The order of magnitude on asymmetry is 0.3-0,4 (downlink latency divided by uplink latency)
- under challenging conditions mainly uplink performance starts to degrade i.e. uplink latency starts to increase.

B. Improved clock adjustment algorithm

The remainder of this section focuses on utilizing 4G radio channel characteristics to (a) develop an improved clock adjustment algorithm, (b) to modify NTP client running in the client device to include the improved algorithm, and (c) as the last step to evaluate the performance of the improved algorithm.

First, we quantify how strongly challenging conditions increase the asymmetry in the radio channel. This is done by monitoring how strongly an increase in roundtrip time, reported by ntpq -p, correlates with the increase in reported

offset, while keeping the client device clock accurate by utilizing a fixed LAN connection to an NTP server as explained in section IV. Strong correlation shows that asymmetry is increasing as the roundtrip time increases. Consequently, NTP would incorrectly report an increasing positive offset when roundtrip time increases.

While calculating correlation by utilizing the data reported in Table I, correlation between roundtrip time and NTP's offset turned out to be 0.85 indicating a strong correlation. When roundtrip time increases, asymmetry increases leading to an increase in NTP's incorrect offset. Based on the previous sub-section, the likely reason to this is that the uplink performance is degrading while downlink is roughly maintaining its performance level.

Now we can utilize this information to develop an improved NTP adjustment algorithm to calculate an estimate for the correct, actual offset, *corrected_offset* (3). As basis we take a typical uplink radio interface as reported in [14]: 20 ms latency in uplink and 7 ms latency in downlink. This results in the NTP to an offset error of $(20-7)/2 = 6.5$ ms as explained in sections III and IV. This typical offset error estimate, *typical_asymm_error*, should be subtracted from the offset reported by NTP, *offset_ntp*.

The result should then be further corrected by subtracting the impact of the possible asymmetry increase. An increase in the roundtrip time reflects increased asymmetry, as explained earlier. To do the correction, we subtract the roundtrip time reported by NTP from the typical roundtrip time of 27 ms in [14]. These are denoted as *roundtrip_ntp* and *typical_roundtrip* in (3) respectively. Correlation factor, *uplink_correl* in (3) indicates how big portion of the increase in roundtrip time results in increase in asymmetry. And 50% of this increase results in an additional error in the offset reported by NTP, as explained in sections III and IV. This estimated asymmetry increase impact is subtracted, together with *typical_asymm_error*, from the offset calculated by NTP, *offset_ntp*. Thus we get an estimate for correct offset, *corrected_offset* as defined in (3).

$$\text{corrected_offset} = \text{offset_ntp} - \text{typical_asymm_error} - \text{uplink_correl} * (\text{roundtrip_ntp} - \text{typical_roundtrip}) / 2 \quad (3)$$

Next, we implement this improved adjustment algorithm, to Ubuntu's ntpq utility running on the client device. We call this utility *m_ntpq*. Key parts of the implementation are shown in Fig. 4 below.

```
//
// Adjusted offset calculation
//
double offsetfloat; /* offset calculated by NTP */
double delayfloat; /* delay calculated by NTP */
double corroffsetfloat; /* adjusted offset */
corroffsetfloat = 0.0;
//
// If the NTP timing source is the core through a 4G connection, calculate the adjusted offset
if (strcmp(clock_name, "172.16.0.1") == 0) {
    offsetfloat = strtod(lfptoms(&stoffset, 3), NULL);
    delayfloat = strtod(lfptoms(&stdelay, 3), NULL);
    corroffsetfloat = offsetfloat - 6.5 - 0.85*(delayfloat-27.0)/2.0;
    //Adding adjusted offset to the ntpq -p output
    printf("                                Corrected offset: %8.3f \n", corroffsetfloat);
}
```

Fig.4. Key parts of the improved adjustment algorithm implementation in ntpq utility running on the client device

C. Verification of the improved adjustment algorithm

We then evaluate the improved adjustment algorithm in our testbed (section IV). As can be seen in both Fig. 5 and Fig. 6 m_ntpq is able to estimate the offset with about 2ms accuracy in a situation where standard NTP is constantly showing and essential positive offset of 11-12 ms.

Fri 29.3.2019 18.45.28 +0200									
m_ntpq remote	refid	st	t	when poll reach	delay	offset	jitter		
*10.11.0.25	.TBLT.	1	u	8 8 377	0.162	0.000	0.019		
172.16.0.1	192.168.9.1	4	u	2 8 377	38.787	11.851	1.409		
						Corrected offset:	0.342		
Fri 29.3.2019 18.46.18 +0200									
m_ntpq remote	refid	st	t	when poll reach	delay	offset	jitter		
*10.11.0.25	.TBLT.	1	u	2 8 377	0.167	0.001	0.031		
172.16.0.1	192.168.9.1	4	u	4 8 377	38.769	11.941	0.052		
						Corrected offset:	0.439		
Fri 29.3.2019 18.47.08 +0200									
m_ntpq remote	refid	st	t	when poll reach	delay	offset	jitter		
*10.11.0.25	.TBLT.	1	u	4 8 377	0.179	-0.002	0.030		
172.16.0.1	192.168.9.1	4	u	6 8 377	38.774	11.983	0.162		
						Corrected offset:	0.479		

Fig. 5. Improved adjustment algorithm correcting the offset

Fig. 6. Comparison of the standard NTP performance (blue line on the top) with the improved NTP adjustment algorithm performance (red line on the bottom)

VI. 5G FUNCTIONALITY IMPROVING NTP

3GPP (The 3rd Generation Partnership Project) completed the work with the first phase of 5G specifications, Rel-15, in June 2018. Work is now continuing with phase two, Rel-16, targeted to be ready by the beginning of 2020 [14], [16]. These releases introduce concepts which will improve possibilities to provide accurate timing to smart grid measurement and control devices and to further improve the performance of the proposed adjustment algorithm. These concepts are discussed in this section.

Current 2G, 3G and 4G cellular networks are fundamentally top-down networks. The traffic from base stations (eNodeBs) is routed through a centralized gateway to its destination and vice versa. The centralized Packet Data Network (PDN) Gateway (P-GW) can be hundreds of kilometres or more from the base station. Even though UE (User Equipment) traffic would be targeted to a nearby UE, it always traverses all the way to service providers centralized

P-GW and back. This inevitably leads to long delays. Typical signal propagation speed in a single mode fiber is 200 kilometres in a millisecond. Long distances also mean active switching devices on the way to the P-GW. These switching devices will be generating additional delays.

5G cellular network specifications and plans include concepts which will gradually enable a change from the hierarchical, relatively fixed top-down structure to a more meshed, dynamic structure [8],[17],[18],[19]. Both the core and transport functionality will be software, cloud and service based instead of consisting of hardware devices and their interfaces. Network Function Virtualization (NFV) enables software implementation of the 5GC core functionality like UPFs, AMFs and SMFs (Fig. 2). These can be deployed on standard computing resources. Network slicing enables creation of application and customer specific 5GC cores. Software Defined Networking (SDN) separates the control functionality from forwarding nodes to software based SDN controllers which can likewise run on standard computing resources. This softwarization enables greatly improved flexibility and possibility to rapidly establish new services tailored and optimized for particular customer and application needs.

In 5G networks, software based UPFs (Fig. 2) will replace 4G's P-GW. There can be numerous UPFs and they can be located close to the UEs and base stations. This enables user traffic breakout close to the UEs and base stations. Applications could then be placed close to the UPFs enabling short latencies. Among these applications could very well be smart grid management applications and among users smart grid operators. One of the applications could be timing and measuring point calibration services for smart grid devices. MEC, Mobile Edge Computing, is a 5G concept enabling 5G network operators to offer local hosting for the services running close to the base stations. It could be noted that the testbed used in this study (section IV) resembles this situation as the 5GC core resides in the same premises as the base station.

Furthermore, 5G has a new radio interface enabling essentially shorter delays and increased reliability [14], [19], [20]. It also includes a specific service category, URLLC (Ultra-Reliable Low Latency Communications), aimed for critical applications having stringent latency and reliability requirements. The ultimate target of URLLC is to have a roundtrip delay of less than 1 ms and a reliability of 99,999% Reliability is defined as probability to deliver a layer 2 packet successfully [20].

URLLC would also set an upper limit for NTP timing error. Assuming the extreme situation that downlink latency would be 0 ms and downlink 1 ms, the error would be 0,5 ms according to (1) and (2). This could ultimately enable a sub-millisecond level timing to UEs. Not to impair the timing accuracy, the timing sources should be placed close to the 5G base stations, gNBs. The backhaul network planning should be done carefully to ensure that the path between the timing source and the base station is symmetric.

VII. CONCLUSIONS AND FUTURE WORK

Smart grids are a key enabler in creating carbon free energy systems. But they also introduce a network

management challenge due to increased complexity and unpredictability. To address this challenge, smart grids will be extensively utilizing communications and information technologies. For many of these applications, time synchronization of smart grid control and measurement devices is a necessity.

In this paper we studied the potential of NTP to deliver timing to smart grid control and measurement devices over a 4G/5G network. We studied NTP performance in current 4G/LTE networks and discussed the inherently asymmetric characteristics of 4G/LTE radio interface. Based on this, we developed an improved adjustment algorithm and evaluated its performance in a 4G/5G test network. Results show that the improved NTP clock adjustment algorithm has potential to deliver timing with ± 2 ms accuracy level over 4G/LTE networks while the standard NTP is constantly showing an essential positive clock offset (typically 11 -12ms as indicated in subsection V C.) . This is more than enough for many applications like measuring temperatures and vibrations of various smart grid assets like transformers. An 1 ms misalignment corresponds to 18 degrees in voltage and current values and 0,1 ms corresponds about 1,8 degrees in a 50 Hz network. Thus NTP has potential to provide reasonable accuracy for many applications based on voltage and current values but further alignment would in most cases be needed e.g. by utilizing fundamental frequency components of voltages and currents.

Going forward, 5G will essentially improve NTP's potential and the performance of the proposed algorithm. This is due to the new radio interface having lower latencies and due to a flatter and more flexible network structure. The new network structure enables optimized services for critical smart grid applications, including having timing sources e.g. regionally closer to the smart grid control and measurement devices.

Future work includes further studies and algorithm development by utilizing 5G base stations and terminals as those start to become available. These devices should be deployed into the utilized test network later this year. In case URLLC will not be fully available in 5G, the enhanced Mobile Broadband (eMBB) could still provide an improvement over 4G. In this case the latencies are also higher than in URLLC. Whether the required level of service for smart grids could be implemented over eMBB remains a research topic. The algorithm development might include activities like studying possibilities of utilizing NTP message time stamps to estimate the level of asymmetry variation.

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