Study Committee D2

Information Systems and Telecommunication

Paper 10547_2022

SEAMLESS EXTENSION OF FIBRE OPTICAL IP/MPLS NETWORK WITH 5G TECHNOLOGY RELEASES ALLOWING BUSINESS SERVICE SEGREGATION, PRECISION TIME SYNCHRONIZATION AND CRITICAL TELEPROTECTION SERVICES IN UTILITY DISTRIBUTION NETWORKS

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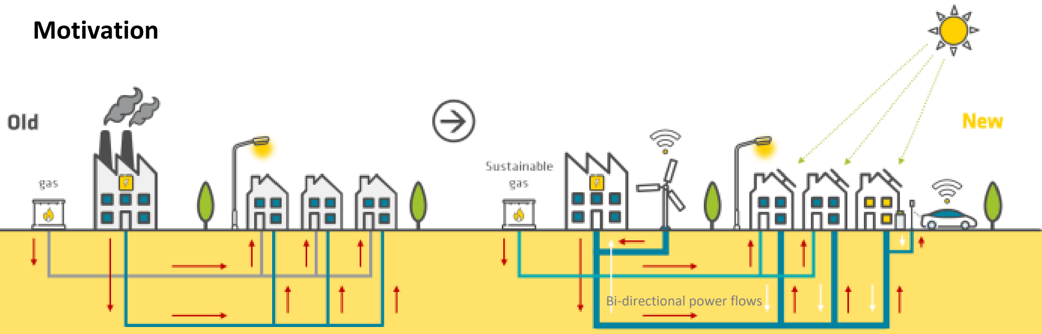
Motivation



- Electrification (ever-increasing demand of electricity)
- Proliferation of (distributed) renewable energy sources;
- Actual protection schemes (time over current) not adequate anymore
- More insight in distribution networks required
- Increasing cyber security requirements (CIA) on data/information traffic flows

- Increasing need for Protection, Automation & Control in distribution grids (MV, LV); Differential protection; CPC; WAMPAC; PMU's; MU's;
- Tens of thousands or even hundreds of thousands of data points will need connectivity
- No wired communication infrastructure, very time consuming and expensive to build and maintain

Objects of investigation

There are relatively high requirements for line differential protection communication, which are challenging for mobile networks (3GPP Rel.16 TR 22.804, 5.6.6 and 3GPP Rel.18 TR 22.867, 5.4.1.):

- Continuous communication based on IP unicast and multicast, with up to approx. 1 Mbit/s in uplink and downlink direction.
- Maximum end-to-end communication latency 5 ms to 10 ms with latency asymmetry < 2 ms.
- High reliable communication with minimum corrupted and dropped packets (< 1 %).
- High available communication (service availability at least 99,9999 % or 99,95% according to IEC 60870-4, class A3) with minimum recovery time.
- High precise and reliable time synchronization of protection relays via the 5G network, based on IEEE 1588v2 with the PTP profile according to IEC 61850-9-3.

How do those requirements fit with the features in the 5G Releases? New releases are available to address the stringent timing and security requirements. 5G offers:

- segregation of services (layer 2 and 3 services via 3GPP 5G LAN-VN),
- precision time synchronization (via 3GPP 5G_TSN) and
- time critical communication services for teleprotection (expected to develop from the 3GPP Release 18 work item FS_5GSEI).

Method/Approach

- The method for investigation has mainly been a theoretical paper exercise studying the different 5G Releases

Conclusion

To meet the challenges of DNO's in distribution networks, 5G provides and enables the opportunity to respond quickly and flexibly to the rapid changes arising from the energy transition. 5G_LAN service offers private communication using IP and/or non-IP type communications as a service over the 5G system. FS_5GSEI, a 3GPP Release 18 WG SA1 Technical Report addressing critical services in smart grids is also recommended, the normative requirements are captured in TS 22.104. Furthermore, as timing is an important requirement for the correct working of the differential protection, the 5G network can be considered as a PTP boundary or transparent clock, according to 3GPP Rel.17 TS 23.501, 5.27.1.1. PTP with definitions according to the IEC 61850-9-3 PTP Power Utility Profile or IEEE C37.238:2017 PTP Power Profile can be used (see 3GPP Rel.18 TS 22.104, 5.6.1). In addition, the 5G robustness toolbox increases resiliency in the 5G network with standardized and vendor-specific network features offering more flexibility to mobile operators to activate appropriate mechanisms depending on the use cases, deployment variants and UE's. Improving the overall observability of the network as well as automation in the correction of network failures, is key to improving network reliability and resilience.

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5G Releases features

The 5G releases in this work are described in terms of what they can offer to support the business needs in a DSO landscape and how they can cope with the challenges on **latency**, **synchronization**, required bandwidth, **network segregation** and **resiliency**.

Latency

- The 5G system shall support an end-to-end latency of less than 5 ms or 10 ms, as requested by the UE initiating the communication.
- The 5G system shall support communication channel symmetry in terms of end-to-end latency (latency from UE1 to UE2, and end-to-end latency from UE2 to UE1), with an asymmetry of < 2ms.
- In 2019, 3GPP approved a Release 17 work item on enhanced cyber-physical control applications for vertical industries, which ensures the 5G could provide communication services supporting enhanced time-sensitive networking (TSN) defined by IEEE 802.1 working group.

Synchronisation

- The 5G system shall provide a suitable means to support precise time distribution, clock synchronization communication functionalities specific to smart grid applications, e.g.: IEC 61850-9-3 profile and IEEE Std C37.238-2017.
- Release 17 work item on enhanced cyber-physical control applications for vertical industries, which ensures the 5G could provide communication services supporting industrial Ethernet integration including time synchronization and support for different time domains – for DSO that has its own PTP grandmaster, 5G system can be simply perceived as IEEE 802.1 compliant virtual Ethernet TSN bridges to transfer the PTP clock signals to the end device in a MV substation.

User-specific clock sync. accuracy level	Number of devices in one communication group for clock synchronisation	5GS synchronicity budget requirement (note 1)	Service area	Scenario
2	up to 300 UEs	≤ 900 ns	≤ 1,000 m x 100 m	Control-to-control communication for industrial controller (A.2.2.2)
4	up to 100 UEs	< 1 µs	< 20 km²	Smart Grid: synchronicity between PMUs
4a	up to 100 UEs	< 250 ns to 1 µs	< 20 km²	Smart Grid: IEC 61850-9-2 Sampled Values
4b	up to 100 UEs	<10-20 µs	< 20 km²	Smart Grid: IEC 61850-9-2 Sampled Values – Power system protection in digital substation
4c	54/km² (note 2) 78/km² (note 3)	< 10 µs	several km²	Smart Grid: Intelligent Distributed Feeder Automation (A.4.4.3)
4d	up to 100 UEs	<1 ms	< 20 km²	Smart Grid: IEC 61850-9-2 Sampled Values – Event reporting and Disturbance recording

Network segragation

- In 2017, 3GPP approved a Release 15 work item on the communication service requirements for automation in vertical domains enabling **5G-LAN services**, to create VLAN services in the 5G system, and set up, configure and maintain a defined set of UEs (e.g. an IED) in this VLAN as needed by specific industry applications. VLAN → MPLS VPRN
- In 2019, 3GPP approved a Release 17 work item on enhanced cyber-physical control applications for vertical industries, which ensures the 5G could provide communication services supporting isolation of different communication services and non-public networks (NPN) as private network slices with enhancement of security.

Resiliency

- Cloud native implementations of 5G core allows the support of "fail fast, recover fast" principle to ensure internal resilience between software components; The general In-Service performance requirement on network function availability for mobile broadband services is 99.999 % and the requirement for 5G-critical services (e.g. industrial manufacturing) is even up to zero tolerance of failure interruption.
- Communication is a part of the overall chain and should match with the power autonomy policy of the utility company. Four to eight hours power autonomy is very common for DSO's, meaning that the 5G network should at least have battery backup for the same amount of time.
- Implement backup protection schemes that do not rely on communication.

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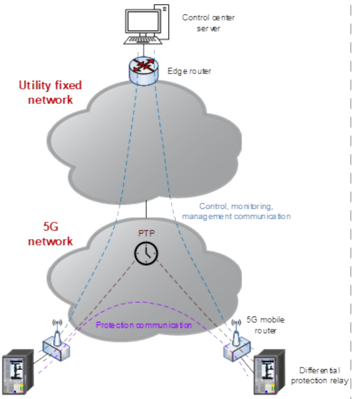
continued

Proposed High-level architecture

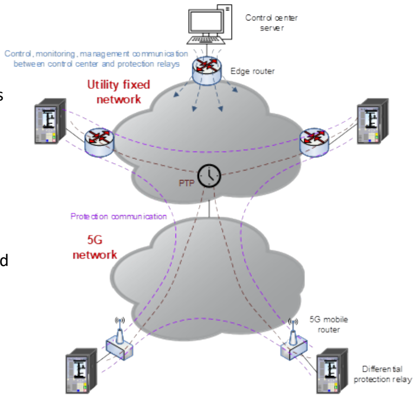
Scenario 1: Protection IEDs with monitoring and control, 5G as backhaul to private fibre optical network

- Namely line differential protection relays, with Ethernet communication interfaces are connected via mobile routers to the 5G network
- Various application layer protocols can be use:, e.g. IEC 61850 Routable GOOSE, Routable SV or vendor-specific IP based protection protocols.
- Time synchronization on microsecond accuracy level is provided by the 5G internal system clock as synchronization source and by help of IEEE 1588 Precision Time Protocol (PTP) to the protection relays. The 5G network can be considered as a PTP boundary or transparent clock, according to 3GPP Rel.17 TS 23.501, 5.27.1.1. In particular, PTP with definitions according to the IEC/IEEE 61850-9-3 PTP Power Utility Profile or IEEE C37.238:2017 PTP Power Profile can be used here, please see 3GPP Rel.18 TS 22.104, 5.6.1. Both profiles prescribe use of the PTP peer delay mechanism and Layer 2 multicast PTP message transport.



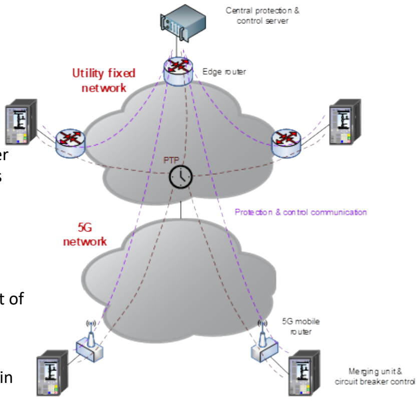
Scenario 2: Multi-branches topology with hybrid underlaying communication

- A hybrid scenario where line differential protection relays are connected to the 5G network (like scenario 1) but there are additionally other relays connected via edge routers to the utility fixed communication network.
- This results in 3 communication paths: protection communication between devices connected to the 5G mobile network, between devices connected to the utility communication network and between devices connected to one and devices connected to the other network. In latter case the protection communication passes through the interconnection point between the two networks. The same protection protocols are used as in scenario 1.
- There is a single synchronisation source connected to the utility network and time synchronization is provided to all protection relays by PTP through the utility and the 5G network in boundary or transparent clock role. The PTP time synchronization domain spans over both networks.



Scenario 3: CPC, WAPC, WAMPAC

- This scenario is applicable to power automation use cases like Central Protection & Control (CPC) and Wide Area Monitoring, Protection & Control (WAMPAC). Protection communication runs, in contrast to the previous discussed scenarios, in star topology between a central protection & control server connected to the utility wide area communication network and multiple protection relays connected either to the utility enterprise or the 5G mobile network. The protection relays can be e.g. process bus merging units, circuit breaker control units or phasor measurement units.
- The protocols can be e.g. IEC 61850 R-GOOSE, R-SV, IEEE C37.118 synchrophasor and other, standardized or vendor-specific, IP based protocols. The communication latency requirements are lower than that of line differential protection: 15 – 20 ms instead of 5 – 10 ms.
- High-accurate time synchronization of the central server and the protection relays is essential. The same synchronization architecture as in scenario 2.



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