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URLLC in B5G Networks: Use cases, TSN/DetNet extension, and Pending issues

Aiman Nait Abbou, Konstantinos Samdanis, Tarik Taleb, and Jukka Manner.

***Abstract*—Originally, 5th Generation (5G) mobile networks were expected to carry the demands of the Internet of Everything (IoE) and Ultra-Reliable and Low-Latency Communications (URLLC) services. However, state-of-the-art of wireless mobile technologies failed to meet these expectations. Beyond 5G (BG5) wireless networks have the potential to leverage the benefits of a mature transported network, and enhanced capabilities related to high reliability and extremely low End-to-End Latency. This paper investigates the potential of B5G with extreme URLLC use cases. It also provides an overview and vision of the potential integration of B5G with Time-Sensitive Networking (TSN) for indoor scenarios, and Deterministic Networking (DetNet) with Segment Routing (SR) for outdoor scenarios.**

***Index Terms*—URLLC, B5G, TSN, DetNet, SR.**

I. Introduction

In order to maintain the steady evolution of wireless mobile networks and keep providing higher data rates, the growth of network capacity was inevitable. The explosion of the Internet of Everything (IoE) connects billions of people, things, machines, and processes. 3rd Generation Partnership Project (3GPP) has led the shift from 5G phase 1, which is based on rate-centric enhanced Mobile BroadBand (eMBB) toward 5G phase 2 which deals with the remaining scenarios including Ultra-Reliable Low Latency Communications (URLLC) and massive machine type communications (mMTC). URLLC specifically with the new emerging services such as high-precision robot control and extended reality (XR) are expecting 99.99999% (7-nine) End-to-End (E2E) reliability, and a latency below 1 millisecond (ms), much like Ethernet-based Time-Sensitive networking (TSN). However, Despite the efforts from 3GPP, the current state of the wireless mobile networks still cannot deliver such strict requirements mainly due to transport network limitations [1].

The emerging Sixth Generation (6G) wireless systems are expected to overcome the limitations of 5G. This upcoming generation will be designed specifically to fit the performance requirements of IoE. For instance, 6G will combine both the current trends (e.g. active multi-antenna arrays for better coverage, higher data rates, and throughput) and future trends (e.g. Artificial Intelligence (AI), computing and sensing) to assure a delay below 1 ms and a reliability of 7-nine over the air. Table 1 summarizes the expected requirements of Beyond 5G (B5G) compared to 5G and 6G.

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TABLE I
COMPARISON OF 5G, BEYOND 5G AND 6G

Parameter	5G	B5G	6G
Peak data-rate	10 Gbps	100 Gbps	1 Tbps
EED Delay	5 ms	1 ms	<1 ms
EED Reliability	99.999%	99.9999%	99.99999%
Processing Delay	100 ns	50 ns	10 ns
Radio-Only Delay	100 ns	100 ns	10 ns
Energy efficiency	1000x (4G)	1000x (4G)	10x (5G)
Mobility	350Km/h	500km/h	>1000km/h
Spectral efficiency	30 bps/Hz	40 bps/Hz	100 bps/Hz

URLLC services may have unique delay and reliability tolerances, for instance, getting the lowest possible delay and the highest reliability is not always required, besides the fact that this is highly challenging and not cost-effective. Thus, a trade-off between delay and reliability needs to be considered depending on the service specifications [1]. In particular, URLLC may be introduced to assist various types of services. URLLC may assure that every flow packet: (i) conforms to the desired delay bound, (ii) receives immediate and highly robust delivery, or (iii) is compliant with a relative latency bound that is defined in coordination among two or more entities.

The IEEE 802.1 TSN and the emerging IETF deterministic networking (DetNet) aim to provide deterministic networking standards with low bounded latency, ultra-reliability, efficient resource management, and time synchronization. These standards are highly capable of delivering a packet within a determined time, which make them a perfect match for providing the transport network for enabling 5G URLLC.

This paper introduces a study of the potential of B5G wireless systems with emerging use cases known for extremely stringent delay and reliability requirements (Section II). Section III, provides the main contributions of this paper, which include a vision of the potential of Artificial Intelligence/Machine Learning (AI/ML) analytics in URLLC. Afterward, a forward-looking to the potential combination of B5G system with: 1) TSN for an indoor use case such as Robotic Control (RC) in a Smart Factory (SF); 2) DetNet coupled with Segment Routing (SR) for outdoor use cases. Finally, Section IV draws the main conclusions.

II. Industrial URLLC Use Case in B5G

At every stage of a cellular generation, innovative applications worked as a driving force leading to the evolution of mobile technologies. The emerging networking technologies could be able to offer better efficiency, flexibility, diversity,

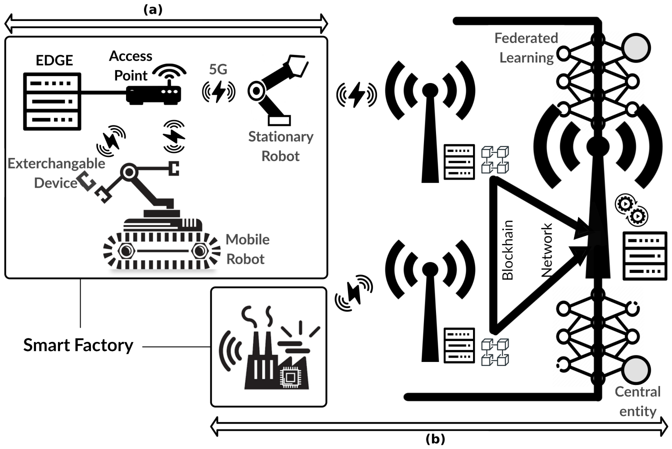

Fig. 1. Indoor wireless robotic control communication scenario with mobile and exchangeable components (a); Scenario illustrating FL data processing for smart factories communications (b)

and intelligence to the new IIoT applications. To satisfy the delay and reliability requirements of these applications, IIoT networks design has to be tailored to fit various demands :

- **Network architecture :** One common architecture should be able to support different demands for each vertical. Therefore, transparency between the IIoT applications and the network infrastructure, protocols, and technologies is crucial to prevent unnecessary modifications over the verticals.
- **Flexibility and scalability :** Flexible manufacturing

3GPP determined use-cases, potential specifications, and communication concepts in 5G for automation in vertical domains. This vision of ”Factories of the Future” aims to expand the cellular technologies in smart factories by improving flexibility, efficiency, and production speed. Next we will discuss few URLLC use cases that will benefits from the upcoming B5G. Likewise, wide area or outdoor use cases also emerged that need to use core network and Internet connectivity for reaching cloud infrastructures located beyond the network edge.

A. Indoor URLLC – Robotic Control in Smart Factory

Wired systems are capable of delivering deterministic services for industrial use cases with rigid demands. Nevertheless, the transition to a wireless system seems inevitable. Cable removal will unlock features such as flexible reconfiguration, and efficient maintenance. In a smart factory, robotic systems are expected to generate heterogeneous data, mostly from multiple sources. These communications are entitled to strict latency and reliability characteristics. Real-time robotic control is expected to be intelligent and reactive to environmental circumstances, thus the industrial robots will be equipped with multiple sensors, complex algorithms, and moving parts for efficient control. Higher computing capabilities are also critical. therefore, processing the data remotely is hard to achieve without delay and reliability guarantees. Currently, B5G systems seem to be the right answer for a wireless system capable of hosting this use case. Figure 1 (a) illustrates how a mobile or customized part of a robot can be connected directly to the access point through a 5G communication. 3GPP had to exploit several techniques (e.g. short packet transmission, grant-free mechanisms, leveraging spatial, frequency, and temporal diversity techniques to support this use case [2]), we can summarize robotic control specifications for B5G as follows :

- **Low-Latency** : Also called cycle time, it is the amount of time needed by a control system from triggering a command and carrying it to the actuator/sensor, until receiving feedback confirming the successful delivery of the command. This use case demands a 1 ms latency.
- **Ultra-Reliability** : or availability, it is the percentage of successful transmission deliveries. As the down times are extremely costly, the system dependability should be at least 99.9999% (6-nine).
- **Density**: Refers to coverage or the service area where the targeted performance should be guaranteed. An indoor use case like robotic control stands for a local network varying from a few tens to hundreds of meters.

B. Outdoor URLLC – Edge Intelligence

AI-based solutions are expected to support decentralization in the future wireless systems, as of right now the new emerging Federated Learning (FL) is becoming popular recently. Introduced by Google and unlike traditional AI algorithms, FL aims to train statistical model over multiple decentralized remote devices with the local data, the locally trained models are then sent to the central entity which aggregate these local models to make a global model. FL does not rely on synchronization within the local model and not only enhances the privacy of the users but also reduces unnecessary overheads which can improve resource utilization [3]. Figure 1 (b) shows a scenario of FL data processing.

- **Low-Latency**: FL performs the training to establish edge intelligence. Solving the problem of finding the optimal position between learning accuracy and the cost of the learning operation can significantly improve resource allocation, and system efficiency and as a result reduces the overall latency.
- **Ultra-Reliability** : Due to the dynamic computing and the resources being moved to the edge, affiliating the end user to the edge server is critical. Moreover, since the end users lack mutual trust, Blockchain can be used to enhance security leading to more reliable communications.

III. Supporting Mechanisms and Technologies

A. Artificial Intelligence/Machine Learning (AI/ML) analytics

AI/ML analytics adapt the producer-consumer model. The consumer subscribes, makes requests, and negotiates with the producer, whereas the producer collects the data from multiple sources, e.g., Network Functions (NFs), Management Services (MnSs), Key Performance Indicators (KPIs), etc.; runs the AI/ML models and use AI/ML analytic orchestrator to make a decision, before the final result is reported back to the consumer. The operation processes are shown in figure 2.

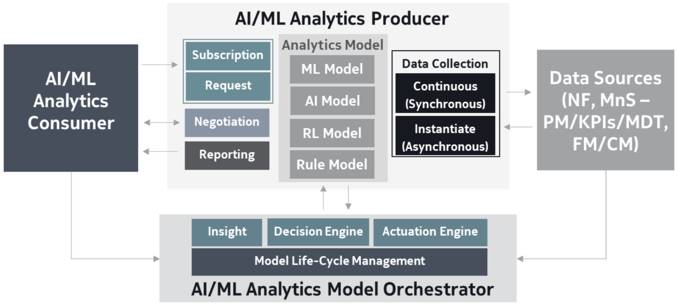

Fig. 2. AI/ML analytics service enablers

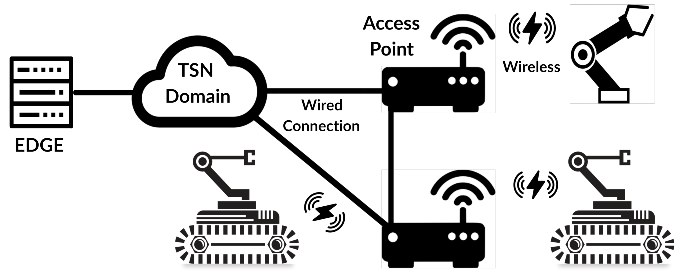

Fig. 3. URLLC wireless mobile robot use case coupled with TSN

This AI/ML service can run through multiple technological domains, i.e., 5G core, transport network, radio, and edge. which can be managed by different administrators. Emerging techniques like zero-touch management and orchestration in the support of network slicing at massive scales make this approach feasible, even on a fully distributed design as proven in the EU-funded Horizon 2020 project, MonB5G [4].

1) AI/ML analytics impact on URLLC: AI/ML analytics will be a key factor in next-generation wireless mobile networks, especially for URLLC use cases. The high Latency is one of the challenges in the current 5G designs as there is always a trade-off between latency and reliability. the sub 1ms needed by most of the future URLLC use cases can be achieved through a tailored low-latency design of the radio resources. As the current designs of 5G networks allocate a massive amount of bandwidth to eMBB traffic. While mMTC traffic raises the complexity and the difficulties of resource scheduling. AI/ML analytics can be deployed as a proactive approach based on predictions which can significantly decrease the latency. This work uses a delay-aware traffic scheduling algorithm based on a Deep reinforcement learning mechanism, which results in an overall decrease in the average delay compared to the state-of-the-art algorithms [5]. Reliability in the current design of 5G networks is tied to multiple elements, e.g., Modulation and Coding Schemes, time-frequency resource (physical resource block), transmit power, number of antennas, etc, With the current 5G designs, to ameliorate the reliability we need to increase the number of retransmissions. which directly affects the latency. AI/ML analytics can be used to decide the size of the transmitted data, a smaller packet size needs lower checksum processing time and eventually improving the reliability. Moreover, proactive traffic shaping will lead to better reliability [6].

2) Pending issues: The main potential problem with AI/ML analytics is the concept drift when the model is fed with erroneous data. The quality of the analytics is tied to the quality of the data the model is trained with. Eventually, the accuracy of the results can decrease over time which can lower the performance of the analytics and thus affect the reliability and latency of the URLLC slices. This is why the maintenance of the AI/ML analytics models is required after the deployment to detect any potential drift and correct it before the quality of the services is impacted [7].

B. Time-Sensitive Networking (TSN)

TSN task group was established after the success of its predecessor Audio Video Bridging (AVB), the goal at first was to reduce the latency to microseconds in order to meet the requirements of the industries interested in time-sensitive applications. TSN has several benefits including being :

- Open technology, in other words the very known problem of incompatibility of several fieldbuses is no longer an issue.
- Part of Ethernet standard series, which means TSN can be extended to Ethernet, Topology changements can be monitored through standard protocols.
- Offers the convergence between the critical and non-critical systems, the traffic from both systems (Critical and non-critical) can share the communication channel.
- Implemented on the data link layer (Layer 2) and can be combined with higher level protocols.

1) TSN for indoor URLLC: Taking the already established TSN to a wireless system can be extremely valuable in terms of mobility, flexibility, and maintenance costs. Several use cases have already been published, on this paper, we will focus on the indoor URLLC robotic control in a smart factory, a scenario example is shown in Figure 3.

Mobile robots are known for special requirements, two main features a wireless system can give this use case: 1) flexibility to reconfigure routes and duties; and 2) Mobility to allow communication between the moving robots and possible emergency stops. Robotic Control requires an availability of 99.9999%, a cycle time of 1 ms (cooperative motion control), and a packet size ranging from 40 bytes to 250 Kbytes (mobile robots) [8].

2) TSN integration within 5G: TSN was first introduced for wired networks, in the previous generations the mobile wireless networks were not ready to be part of TSN, but with the recent big advancements, 5G became a strong candidate to become the first wireless time-sensitive network, 5G has the flexibility lacked on TSN, which qualifies 5G as a perfect match for time-sensitive communications. 3GPP released in phase 2 (release 16) a fully centralized model of this integration (Figure 4).

The 5G System (5GS) is used to connect input/output devices (sensors, actuators, etc..) to the real TSN network.

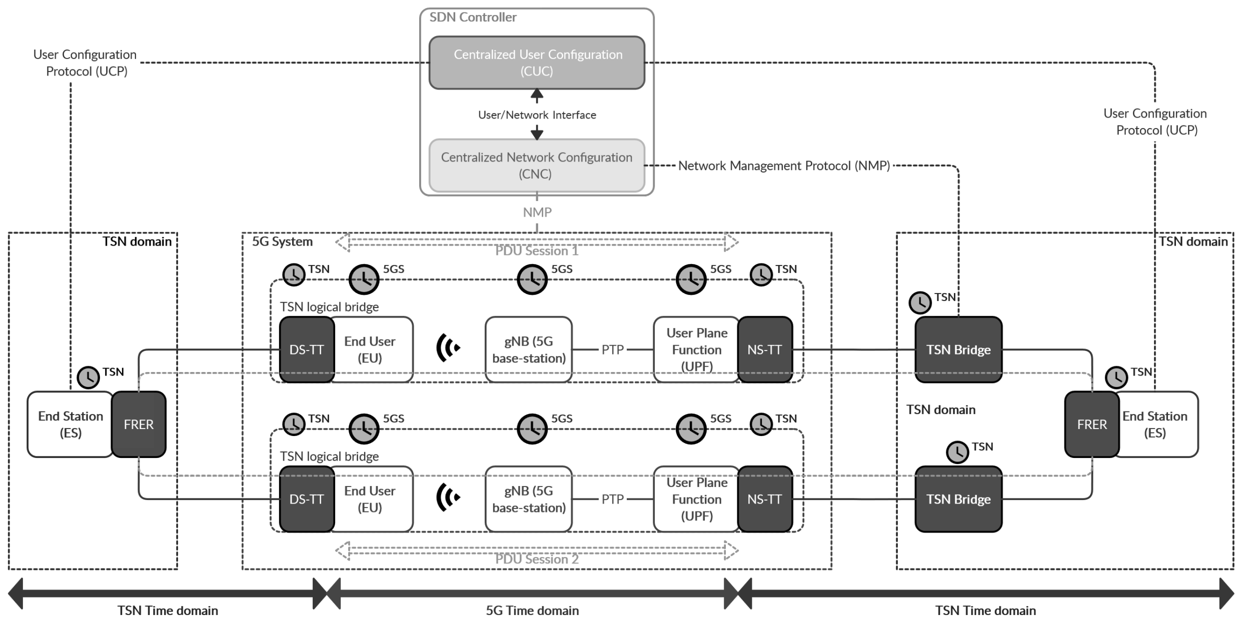

Fig. 4. 5G/TSN integration system with the 5GS appearing as TSN bridge

It takes the role of a logical TSN bridge, TSN translators (TT) are deployed on both ingress and the egress ports to guarantee the inter-operation between the 5G system and the TSN network. Moreover, the operations inside the 5G system are hidden from the TSN network, thus a 5G system can also be deployed to connect TSN bridges. TSN/5G integration features can be listed :

- The jitter can be limited by duplicating the the connection in Radio Access Network (RAN), meaning, each user equipment will have two RANs connections and two Protocol Data Unit (PDU) sessions for redundancy.
- The ultra reliability is provided by Frame Replication and Elimination for Reliability (FRER) on both ends (5G domain and TSN domain).
- The resource management is provided through the interaction between Centralized Network Configuration (CNC) on the SDN controller and the 5G system. The communication between the two interfaces allows the 5G system to initiate connections based on specific parameters received from CNC, and CNC can get features of the 5G logical bridge.
- A Bounded latency is provided by both 5GS and TSN and unlike traditional wired connection, a mobile wireless network does not limit the number of hops as the 5G system is getting the exact required transmission time from the CNC. TT interfaces of the User End (UE), and the the User Plane Function (UPF) can control and regulate the packet transmission process based on the transmission time.
- Time synchronization is also required on both TSN and 5G system, TSN utilize generic Precision Time Protocol (gPTP) for synchronization. As a result, 5G system can act as a virtual gPTP system to provide time synchronization between the end stations and the TSN bridges.

3) Pending issues: The current generation of wireless mobile networks allows distinct Quality of Service (QoS) for each service. In other words, each flow is associated with a 5G QoS profile which includes several parameters, such as: 1) Maximum and Guaranteed Flow Bit-Rate; 2) Maximum Packet Loss Bit-Rate; and 3) 5G QoS Identifier (5QI). 5QI contains metrics like Packet Delay Budget (PDB) which is the maximum amount of time a packet can take between EU and UPF. The current status of the standards proposed by 3GPP has recorded a PDB equal or higher than 5 ms. Therefore, this integration with TSN is not yet ready in industrial use cases. Nokia wrote a white paper to bypass those limitations and reach the 1 ms delay [9], Nokia motivates the usage of semi-persistent scheduling (SPS). Unlike Dynamic Scheduling methods, SPS provides less complexity and reliance on control channel reliability. The performance evaluation of Nokia using SPS has shown a Core Network (CN) PDB lower than 10 s and a one-way latency lower than 60 s with a 99.999% reliability from the CN port to any other user port.

Another issue related the measurement of the 5GS bridge delay, at the moment only the implementation is responsible for this estimation as the correlation of 3GPP parameters and this delay is not yet specified yet. This makes the 5GS PDB hard to estimate before the establishment of TSN flows [10]. Martenvormfelde textitet al. [11] studied this integration of TSN and 5G, the authors highlighted the impact the NR frame structure features and sub-carrier spacing on the EED delay, even in a small-scale network. Therefore, bad scheduling decisions or unsuitable time slot configurations can increase the delay and jitter of communication.

C. Deterministic Networking (DetNet) and Segment Routing (SR)

1) DetNet for Outdoor URLLC: enables a bounded latency and low data loss rates on selected data flows. The respective DetNet QoS can be expressed in terms of:

- Bounded delay and delay variation, i.e. jitter, from source to destination.
- Packet loss ratio under various assumptions as to the operational states of the nodes and links. If packet replication is used then a related property is the delivery probability of extra copies related to replicated packets.
- Tolerance for out-of-order packet delivery, with certain applications being unable to tolerate any out-of-order delivery.

DetNet focuses on worst-case values for the end-to-end latency, jitter, and misordering. To provide QoS the following techniques are used:

- Congestion loss protection addresses latency and packet loss. It operates by allocating resources along the path of a DetNet flow including both buffer and link bandwidth in some or all intermediate nodes.
- Service protection focuses on packet loss due to random errors or equipment failures. Packet replication and elimination or packet encoding via the means of network coding are the adopted techniques for enabling service protection, which are constrained by latency requirements and network resource availability.
- Explicit routes and pinning are used to avoid oscillations and temporary interruptions caused by the update convergence of routing or bridging protocols. Route pinning can also assist sequentialization simplifying the replication/elimination process.

Network resources, e.g. buffer or link bandwidth, not utilized by a DetNet flow are available to other non-DetNet flow packets and may be preempted when a respective DetNet traffic flow needs them. The IETF DetNet working group focuses on aspects related to architecture (RFC 8655), data plane, data flow, and information models. The DetNet working group collaborates with other IETF working groups as well as other standardization bodies including IEEE.

2) Segment Routing IPv6 (SRv6): (RFC 8402) enables source-based steering of packets belonging to a flow via a set of instructions referred to as segments, which are carried using IP options in each packet header. The notion of a segment can represent a topological, local, i.e. inside a switch or router, or service-based semantic. In particular, a segment in the SRv6 can:

- offers source routing capabilities by enforcing a flow through a specified strict or loose path,
- allows the selection of a specific resource, i.e. a link of an aggregated interface, a buffer, or a QoS treatment within a node, or indicates the desired amount of computation and storage resources from a node
- enables a service instruction, e.g. directing a packet to a particular virtual machine, assisting in this way a flexible service chaining deployment.

The adoption of SRv6 requires ingress and potentially selected intermediate node(s) to maintain a per-flow state enabling the provision of segment policies across the network. This allows scalability since there is no need for signaling to configure the nodes across a segment route path. The corresponding policy at ingress points can be:

- Distributed established via routing protocols, e.g. Boarder Gateway Protocol (BGP) or Open Shortest Path First (OSFP), provided that the necessary extensions to handle the distribution of Segment Identities (SIDs) are in place.
- Centralized where segments allocated by SRv6 ingress nodes are established by a Path Computation Entity (PCE) or SDN controller and communicated via the means of the Network Configuration Protocol (NETCONF), OpenFlow, or PCE Communication Protocol.

3) Pending Issues: 5G and DetNet integration consists of two main parts: (i) dynamic establishment of mappings among the 5G QoS flows or slices running on the top with the underlying DetNet flows specifying the expected performance characteristics, which can be achieved by providing a policy at ingress nodes and (ii) awareness of SRv6 capabilities when performing such mapping, i.e. path and buffer selection, for achieving the desired QoS while deploying a flexible service chaining. SRv6 can also be used as a technology to replace the conventional 5G tunneling enabling further flexibility when integrating the 5G layer with the underlying transport one.

D. TSN over DetNet enabled SRv6

In order to interconnect two factories through the Internet while maintaining TSN features, DetNet was proposed in this paper to guarantee TSN services. The architecture can be broken down into two main parts 5, Firstly, a TSN domain on the factory side, where all the local communications are achieved through a wired or a 5G wireless network. Secondly, the DetNet domain where non-DetNet aware L2 flow (e.g. TSN flow) is mapped into DetNet traffic. This mapping process is made by an Edge Node (ED) sitting at the boundaries of each TSN domain, ED can play the role of a source or destination at the DetNet service sub-layer, these nodes also provide the imposition and disposition of the required DetNet encapsulation, insert and remove DetNet SRv6 data plane encapsulation, provide Frame Replication and Elimination for Reliability (FRER). Detnet Service protection using a sublayer proxy function and managing the resource allocation at the DetNet forwarding sub-layer. Relay Node (RN) at the DetNet domain can be seen as a service sub-layer function that interconnects different DetNet forwarding sub-layer paths to provide service protection. RN also can provide FRER feature.

According to the original architecture of DetNet defined by IETF, three functions are defined at the DetNet Domain :

- **Congestion Protection :** This can be achieved by avoiding packet loss and latency because of congestion.

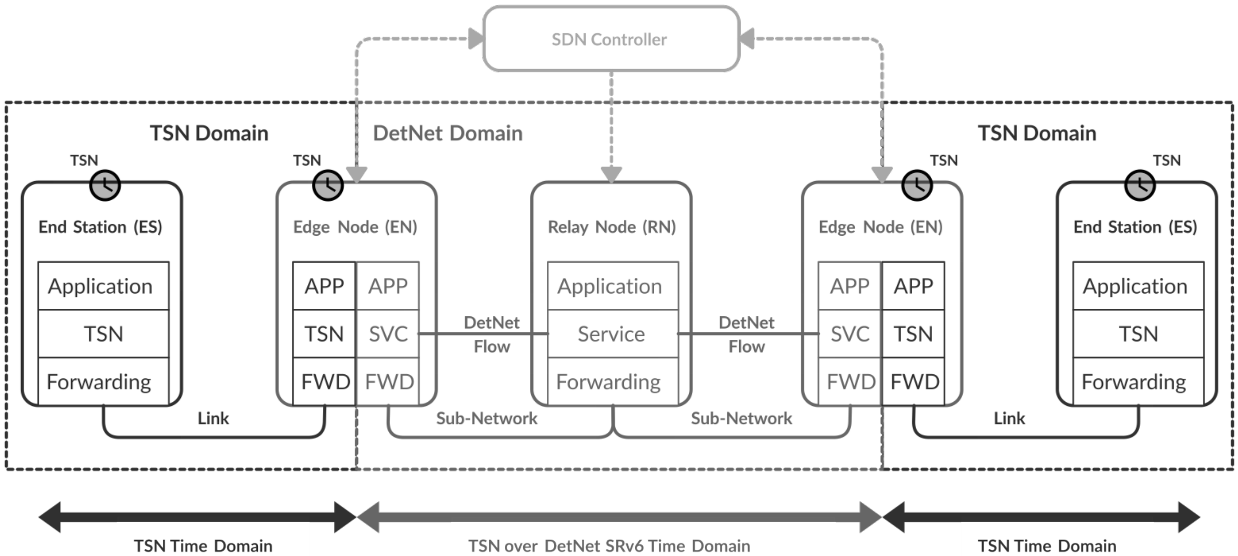

Fig. 5. TSN over DetNet enabled SRv6

Two techniques are used for this purpose : Resource reservation for DetNet flows, and Queuing Management (Shaping, Scheduling, etc.)

- **Service Protection :** means avoiding packet loss because of random media errors and equipment failures. FRER technique is used here.
- **Explicit Routing :** Specify explicit routes to control end-to-end latency. For instance, Segment Routing, RSVP-TE, etc.

IV. Conclusion

This paper provided an overview of B5G URLLC services, considering indoor and outdoor stringent use cases. On this scope, the paper provided a future vision on how other technologies such as AI/ML analytics will help B5G network to fulfill the expectations of these emerging services. The paper also discussed recent research efforts to take TSN and DetNet to the air, and how the industry will benefit from this upcoming transition. Finally, the paper discussed a few pending issues to be addressed by the future standards and the research community.

References

[1] M. U. A. Siddiqui, H. Abumarshoud, L. Bariah, S. Muhaidat, M. A. Imran, and L. Mohjazi, "Urllc in beyond 5g and 6g networks: An interference management perspective," *IEEE Access*, 2023.

[2] M. E. Haque, F. Tariq, M. R. Khandaker, K.-K. Wong, and Y. Zhang, "A survey of scheduling in 5g urllc and outlook for emerging 6g systems," *IEEE Access*, 2023.

[3] C. She, R. Dong, Z. Gu, Z. Hou, Y. Li, W. Hardjawana, C. Yang, L. Song, and B. Vucetic, "Deep learning for ultra-reliable and low-latency communications in 6g networks," *arXiv preprint arXiv:2002.11045*, 2020.

[4] J. J. A. Esteves, A. Boubendir, F. Guillemin, and P. Sens, "Optimizing network slicing in distributed large scale infrastructures: From heuristics to controlled deep reinforcement learning," in *NOMS 2023-2023 IEEE/IFIP Network Operations and Management Symposium*. IEEE, 2023, pp. 1–6.

[5] T. Zhang, "Resource allocation for next generation wireless networks," Ph.D. dissertation, Auburn University, 2022.

[6] P. Raussi, H. Kokkoniemi-Tarkkanen, K. Ahola, A. Heikkinen, and M. Uitto, "Improving reliability of protection communication in a 5g slice," *Authorea Preprints*, 2023.

[7] K. Samdanis, A. N. Abbou, J. Song, and T. Taleb, "Ai/ml service enablers & model maintenance for beyond 5g networks," *IEEE Network*, 2023.

[8] M. Cantero, S. Inca, A. Ramos, M. Fuentes, D. Martín-Sacristán, and J. F. Monserrat, "System-level performance evaluation of 5g use cases for industrial scenarios," *IEEE Access*, 2023.

[9] T. K. Peter M. Rost, Devaki Chandramouli, "How the 3gpp 5g system facilitates industrial ethernet deployments to fuel industry 4.0 applications," 2020.

[10] A. Larrañaga, M. C. Lucas-Estañ, I. Martinez, I. Val, and J. Gozalvez, "Analysis of 5g-tsn integration to support industry 4.0," in *2020 25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)*, vol. 1. IEEE, 2020, pp. 1111–1114.

[11] L. Martenvormfelde, A. Neumann, L. Wisniewski, and J. Jasperneite, "A simulation model for integrating 5g into time sensitive networking as a transparent bridge," in *2020 25th IEEE International Conference on Emerging Technologies and Factory Automation*. IEEE, 2020.