November 07, 2018

END-TO-END TIME-SENSITIVE NETWORKING CONNECTING 5G SLICES

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ABSTRACT

Techniques are described herein for deploying 5G slices in conjunction with Time-Sensitive Networking (TSN) in the backhaul network. The system employs a network controller that both provisions the backhaul device scheduling and path detection, and combines it with the aligned requirements of the 5G slice and builds and enforces a Service Level Agreement (SLA) to meet the TSN needs. The system finally manages the end to end system by connecting the fronthaul 5G network with the wired backhaul network.

DETAILED DESCRIPTION

Latency-sensitive applications, such as Autonomous Guided Vehicles or Augmented Reality / Virtual Reality (AR/VR), are expected to be heavily used in 5G networks. However, the guaranteed latency requirements of these applications are extremely difficult to maintain, especially in an end-to-end scenario.

Institute of Electrical and Electronics Engineers (IEEE) 802.1 Time Sensitive Networking (TSN) has been developed to ensure reliable communications over Ethernet / switched networks and leverages both path control as well as transmission scheduling on each node. While TSN (or a similar mechanism such as Deterministic Networking) may be used on a 5G backhaul network and on the 5G fronthaul, it is not directly compatible with the 5G network where other logic and mechanisms are applied. This limitation breaks the end-to-end structure needed for determinism.

Accordingly, techniques are provided herein to address these challenges and to support TSN co-ordination with 5G network slices to achieve end-to-end determinism.

First, the user defines the applications requirements in the Central User Configuration (CUC) tool. The TSN Central Network Controller (CNC) receives the latency-sensitive application requirements from the CUC tool but also the system capabilities from the 5G controller (e.g., 3GPP Management System).

In general, the CNC is responsible for (1) determining a path that can meet the application requirements and (2) creating the transmission schedule for each node along the end-to-end path. The CNC examines the path comprising the fronthaul network as well as a backhaul network. In case of a midhaul network, this will be included as well.

When the CNC analyzes the path and determines that part of the path traverses a 5G Radio Access Network (RAN), the backhaul (including the fronthaul) and the 5G RAN networks must now be synchronized. To ensure synchronization of the backhaul network and the 5G RAN, the CNC becomes responsible for coordination of both networks. In another embodiment, a dedicated RAN-Controller for the 5G network may be employed. In this case, the primary CNC (on the backhaul network) communicates with the 5G RAN-Controller and synchronizes the application requirements. Here, the hierarchy of the CNC and RAN-Controller must be synchronized and view the front/backhaul networks and RAN as elements supporting a single flow.

The 5G Controller and CNC controllers synchronize their time (e.g., using IEEE 1588 Precision Time Protocol). Based on the application requirements generated in the CUC, the CNC (either the central or fronthaul CNC) computes the 5G slice SLA requirements (e.g., latency, jitter, bandwidth, Quality of Service (QoS), etc.). This involves a translation of requirements into specific 5G slice capabilities, including QoS and security (as-per 802.1Qci). This translation is done during an n-dimensional heuristic analysis, where each QoS parameter is matched against one of the dimensions listed for example in Technical Specification (TS) 22.261 or TS 22.203 (along dimensions such as delivery guarantee requirement, delay budget, loss budget, etc.). These requirements are translated into 5G RAN access and QoS Class Identifier (QCI) rules. The QCI of the closest match to the CNC expressed requirements is applied.

The CNC now pushes the slice requirements and the SLA to the 5G Slice Controller to initiate a new slice that will meet TSN flow requirements. In this way the CNC and the Slice Controller work like federated controllers.

The 5G Slice Controller creates the slice and implements the SLA. The slice is dedicated for this TSN flow. The 5G Slice Controller communicates back to the CNC that the slice has been successfully deployed, and its ability to adhere to the SLA.

The RAN has now become an extension for the TSN flows/stream network. The TSN streams are handed over at the gateway, connecting the fronthaul/backhaul with the RAN. It is the responsibility of the 5G controller to meet the SLA requirements, and the backhaul network utilizes the flow schedules published from the CNC.

Figure 1 below illustrates an example method. The TSN-Endpoints are attached to cells of the Wireless 5G Network on one side and a wired endpoint on the other. However, in other examples they could be connect to another 5G wireless endpoint and/or cloud-based applications (e.g., to realize use cases such as large control-loops).

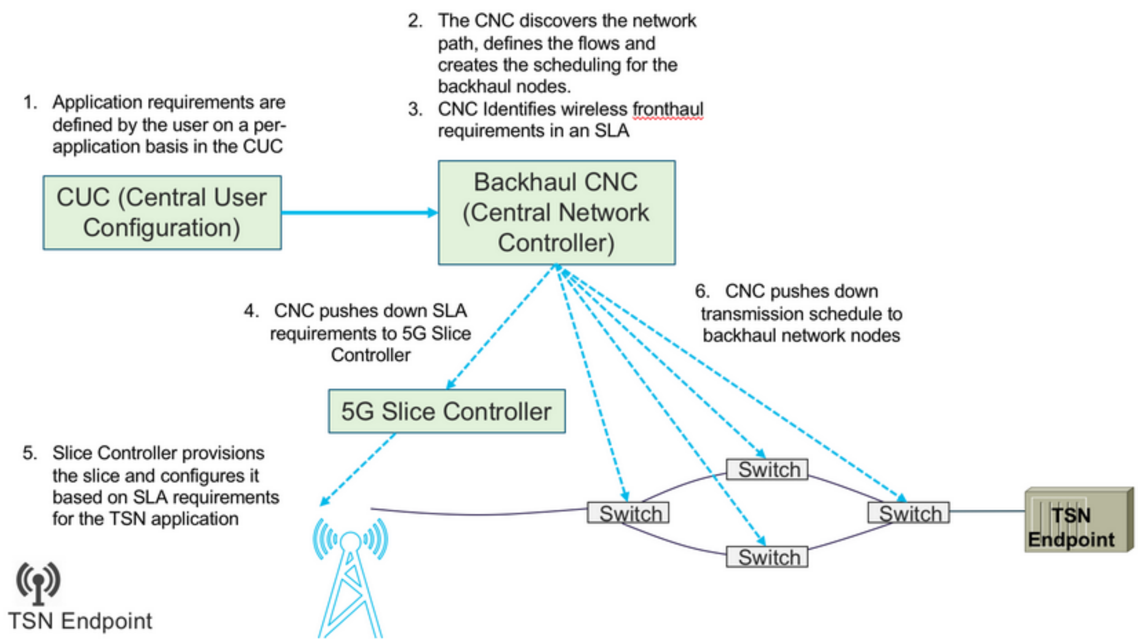

Figure 1

TSN has been developed and deployed for use in wired networks. With the emergence of low-latency 5G networks, there has been much attention given to 5G as a potential candidate to support TSN, especially for latency-sensitive applications, such as autonomous vehicles. These techniques takes an end to end perspective, linking the 5G RAN network with existing TSN components.

This is unique because it takes the latency and scheduling ideas of TSN and translates this to a 5G SLA that will meet the same latency requirements. From a controller perspective, the existing TSN controller capabilities are expanded to determine both the wired and wireless networking path, as well as scheduling the wired switches and the 5G slice requirements.

In essence, there are several efforts underway to apply TSN in portions of the 5G network (e.g., proposal in IEEE for backhaul, IEEE 802.1CM specifies a TSN-profile for the fronthaul, etc.). None of these activities address an end-to-end approach in order to meet the requirements of applications such as large-control loops, virtualized control/digital twins, or autonomous vehicles. They only address a portion of the network. Mechanisms provided herein close the gap and interconnect these fragmented parts in order to achieve end-to-end deterministic network behavior.

In summary, techniques are described herein for deploying 5G slices in conjunction with TSN in the backhaul network. The system employs a network controller that both provisions the backhaul device scheduling and path detection, and combines it with the aligned requirements of the 5G slice and builds and enforces a SLA to meet the TSN needs. The system finally manages the end to end system by connecting the fronthaul 5G network with the wired backhaul network.