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SPAWN use cases
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Abstract

The wireless medium presents significant specific challenges to achieve properties similar to those of wired deterministic networks. At the same time, a number of use cases cannot be solved with wires and justify the extra effort of going wireless. This document presents some of these use-cases.

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1. Introduction

Based on time, resource reservation, and policy enforcement by distributed shapers, Deterministic Networking provides the capability to carry specified unicast or multicast data streams for real-time applications with extremely low data loss rates and bounded latency,

so as to support time-sensitive and mission-critical applications on a converged enterprise infrastructure.

Deterministic Networking in the IP world is an attempt to eliminate packet loss for a committed bandwidth while ensuring a worst case end-to-end latency, regardless of the network conditions and across technologies. It can be seen as a set of new Quality of Service (QoS) guarantees of worst-case delivery. IP networks become more deterministic when the effects of statistical multiplexing (jitter and collision loss) are mostly eliminated. This requires a tight control of the physical resources to maintain the amount of traffic within the physical capabilities of the underlying technology, e.g., by the use of time-shared resources (bandwidth and buffers) per circuit, and/or by shaping and/or scheduling the packets at every hop.

Key attributes of Deterministic Networking include:

- time synchronization on all the nodes,
- centralized computation of network-wide deterministic paths, and
- new traffic shapers within and at the edge to protect the network.

Wireless operates on a shared medium, and transmissions cannot be fully deterministic due to uncontrolled interferences, including self-induced multipath fading. Scheduling transmissions enables to alleviate those effects by leveraging diversity in the spatial, time and frequency domains, enabling Scheduled Predictable and Available Wireless Networks (SPAWN).

The wireless and wired media are fundamentally different at the physical level, and while the generic Problem Statement [I-D.ietf-detnet-problem-statement] for DetNet applies to the wired as well as the wireless medium, the methods to achieve SPAWN necessarily differ from those used to support Time-Sensitive

Networking over wires.

So far, Open Standards for Deterministic Networking have prevalently been focused on wired media, with Audio/Video Bridging (AVB) and Time Sensitive Networking (TSN) at the IEEE and DetNet [I-D.ietf-detnet-architecture] at the IETF. But wires cannot be used in a number of cases, including mobile or rotating devices, rehabilitated industrial buildings, wearable or in-body sensory devices, vehicle automation and multiplayer gaming.

Purpose-built wireless technologies such as [ISA100], which incorporates IPv6, were developed and deployed to cope for the lack

of open standards, but they yield a high cost in OPEX and CAPEX and are limited to very few industries, e.g., process control, concert instruments or racing.

This is now changing:

- o IMT-2020 has recognized Ultra-Reliable Low-Latency Communication (URLLC) as a key functionality for the upcoming 5G,

- o IEEE 802.11 is integrating real-time applications in the charter of the Extreme High Throughput (EHT) Task Group (to be formed at the time of this writing), and

- o the IETF has produced an IPv6 stack for IEEE Std. 802.15.4 TimeSlotted Channel Hopping (TSCH) and an architecture [I-D.ietf-6tisch-architecture] that enables Scheduled Predictable and Available Wireless Networks (SPAWN) on a shared MAC.

This draft extends the "Deterministic Networking Use Cases" [I-D.ietf-detnet-use-cases] and describes a number of additional use cases which require deterministic flows over wireless links and possibly complex multi-hop paths called Tracks.

2. Amusement Parks

2.1. Use Case Description

The digitalization of Amusement Parks is expected to decrease significantly the cost for maintaining the attractions. By

monitoring in real-time the machines, predictive maintenance will help to reduce the repairing cost as well as the downtime. Besides, the attractions may use wireless transmissions to interconnect sensors and actuators, to privileged reconfigurability, and standardization.

Attractions may comprise a large set of sensors and actuators, which react in real time. Typical applications (ordered by criticality in descending order) are:

- emergency: safety has to be preserved. An attraction has to be stopped if a failure is detected;

- real-time control: real-time applications embedded in the attraction need to trigger an action when an event is detected. For instance, a photograph can be taken when a car crosses an actuator, combined with a wireless ID that the tourists wear;

- predictive maintenance: statistics are collected to predict the future failures, or to compute later more complex statistics about the attraction's usage, the downtime, its popularity, etc.

2.2. Specificities

Amusement parks comprise a variable number of attractions, mostly outdoor. Thus,

The tourists are free to move from an attraction to another, covering a large geographical area. Wearable devices are expected for a user experience personalisation. Thus, some devices may be mobile, while the rest of the infrastructure remains static.

The infrastrcuture is typically multi-scale:

- local area: the sensors and actuators controlling the attractions are co-located. Real-time flows are localized, a set of sensors triggering actuators. Maintenance flows are mostly lrage-range, interconnected with the information system;

- wearable devices are free to move in the park. They exchange

traffic locally (identification, personalization, multimedia) or globally (billing child tracking);

- global information system manages the whole park, and exchange commands or information with the different parts.

2.3. The Need for Wireless

Amusement parks cover large areas and a global interconnection would require a huge length of cables. Wireless also optimizes the reconfigurability, enabling to plug novel services easily to increase e.g. the interactivity.

Attractions comprise mobile components (e.g. robots, wagons), which require wireless connections since cables are particulalry inconvenient and source of failures in such conditions.

Wearable devices have to support by nature wireless transmissions. They aim to enable novel high-value services. VIP tickets are nowadays more and more popular. Wireless wearable devices may help to reduce the operating costs [disney-VIP] and increasing the number of charged services provided to the audience (VIP tickets, interactivity, etc.)

2.4. Asks for SPAWN

The networ infrastructure has to support heterogenous traffic, with very different criticalities. Thus, flow isolation has to be provided, where best effort traffic only

We have to schedule appropriately the transmissions, even in presence of mobile devices. While the [I-D.ietf-6tisch-architecture] already proposes an architecture for synchronized, IEEE Std. 802.15.4 Time-Slotted Channel Hopping (TSCH) networks, 6TiSCH focused on best-effort IPv6 flows. SPAWN expects to schedule appropriately the transmissions, across heterogeneous technologies, with strict SLA requirements.

Nowadays, long-range wireless transmissions are used for best-effort

traffic, and [IEEE802.1TSN] is used for critical flows using Ethernet devices. However, we need an IP enabled technology to interconnect large areas, independent of the PHY and MAC layer to maximize the compliance.

3. Wireless for Industrial Applications

3.1. Use Case Description

A major use case for networking in Industrial is the control networks where periodic control loops operate between a sensor that measures a physical property such as the temperature of a fluid, a Programmable Logic Controller that decides an action such as warm up the mix, and an actuator that performs the required action, e.g., inject power in a resistor.

3.2. Specificities

3.2.1. Control Loops

Process Control designates continous processing operations, e.g., heating Oil in a refinery or mixing drinking soda. Control loops in the Process Control industry operate at a very low rate, typically 4 times per second. Factory Automation, on the other hand, deal with discrete goods such as individual automobile parts, and requires faster loops, in the order of 10ms. Motion control that monitors dynamic activities may require even faster rates in the order of a few ms. Finally, some industries exhibit hybrid behaviors, like canned soup that will start as a process industry while mixing the food and then operate as a discrete manufacturing when putting the final product in cans and shipping them.

In all those cases, a packet must flow deterministically between the sensor and the PLC, be processed by the PLC, and sent to the actuator within the control loop period. In some particular use cases that inherit from analog operations, jitter might also alter the operation of the control loop. A rare packet loss is usually admissible, but typically 4 losses in a row will cause an emergency halt of the production and incur a high cost for the manufacturer.

3.2.2. Unmeasured Data

A secondary use case deals with monitoring and diagnostics. This so-called unmeasured data is essential to improve the performances of a production line, e.g., by optimizing real-time processing or maintenance windows using Machine Learning predictions. For the lack of wireless technologies, some specific industries such as Oil and Gas have been using serial cables, literally by the millions, to perform their process optimization over the previous decades. But few industries would afford the associated cost and the Holy Grail of the Industrial Internet of Things is to provide the same benefits to all industries, including SmartGrid, Transportation, Building, Commercial and Medical. This requires a cheap, available and scalable IP-based access technology.

Inside the factory, wires may already be available to operate the Control Network. But unmeasured data are not welcome in that network for a number of reasons. On the one hand it is rich and asynchronous, meaning that using they may influence the deterministic nature of the control operations and impact the production. On the other hand, this information must be reported to the carpeted floor over IP, which means the potential for a security breach via the interconnection of the Operational Technology (OT) network with the Internet technology (IT) network and possibly enable a rogue access.

3.3. The Need for Wireless

Ethernet cables used on a robot arm are prone to breakage after a few thousands flexions, a lot faster than a power cable that is wider inn diameter, and more resilient. In general, wired networking and mobile parts are not a good match, mostly in the case of fast and recurrent activities, as well as rotation.

When refurbishing older premises that were built before the Internet age, power is usually available everywhere, but data is not. It is often impractical, time consuming and expensive to deploy an Ethernet fabric across walls and between buildings. Deploying a wire may take months and cost tens of thousands of US Dollars.

Even when wiring exists, e.g., in an existing control network,

asynchronous IP packets such as diagnostics may not be welcome for operational and security reasons (see Section 3.2.1). An alternate network that can scale with the many sensors and actuators that equip every robot, every valve and fan that are deployed on the factory floor and may help detect and prevent a failure that could impact the production. IEEE Std. 802.15.4 Time-Slotted Channel Hopping (TSCH) [RFC7554] is a promising technology for that purpose, mostly if the scheduled operations enable to use the same network by asynchronous and deterministic flows in parallel.

3.4. Asks for SPAWN

As stated by the "Deterministic Networking Problem Statement" [I-D.ietf-detnet-problem-statement], a Deterministic Network is backwards compatible with (capable of transporting) statistically multiplexed traffic while preserving the properties of the accepted deterministic flows. While the [I-D.ietf-6tisch-architecture] serves that requirement, the work at 6TiSCH was focused on best-effort IPv6 packet flows. SPAWN should be able to lock so-called hard cells for use by a centralized scheduler, and program so-called end-to-end Tracks over those cells.

Over the course of the recent years, major Industrial Protocols, e.g., [ODVA] with EtherNet/IP [EIP] and [Profinet], have been migrating towards Ethernet and IP. In order to unleash the full power of the IP hourglass model, it should be possible to deploy any application over any network that has the physical capacity to transport the industrial flow, regardless of the MAC/PHY technology, wired or wireless, and across technologies. SPAWN should be able to setup a Track over a wireless access segment such as TSCH and a backbone segment such as Ethernet or WI-Fi, to report a sensor data or a critical monitoring within a bounded latency.

4. Pro Audio and Video

4.1. Use Case Description

The professional audio and video industry ("ProAV") includes:

- o Public address, media and emergency systems at large venues (airports, stadiums, train stations, churches, theme parks).

Today the ProAV applications are moving towards packet-based technology to introduce routing features and to reduce costs.

4.2. Specificities

Considering the uninterrupted audio or video stream, a potential packet losses during the transmission of audio or video flows cannot be tackled by re-trying the transmission, as it is done with file transfer, because by the time the packet lost has been identified it is too late to proceed with packet re-transmission.

4.3. The Need for Wireless

4.4. Asks for SPAWN

TBD.

5. UAV control

5.1. Use Case Description

Unmanned Aerial Vehicles (UAVs) are becoming very popular for many different applications, including military and civil use cases. The term drone is commonly used to refer to a UAV.

UAVs can be used to perform aerial surveillance activities, traffic monitoring (e.g., Spanish traffic control has recently introduced a fleet of drones for quicker reactions upon traffic congestion related events), support of emergency situations, and even transportation of small goods.

UAVs typically have various forms of wireless connectivity:

- cellular: for communication with the control center, for remote manuevering as well as monitoring of the drone;

- IEEE 802.11: for inter-drone communications (e.g., coordination of actions, platooning) and providing connectivity to other devices (e.g., acting as Access Point).

5.2. Specificities

Some of the use cases/tasks involving drones require coordination among drones. Others involve complex compute tasks that might not be performed using the limited computing resources that a drone typically has. These two aspects require continuous connectivity with the control center and among drones.

Remote maneuvering of a drone might be performed over a cellular

network in some cases, however, there are situations that need very low latencies and deterministic behavior of the connectivity.

Examples involve platooning of drones or sharing of computing resources among drones (e.g., a drone offload some function to a neighboring drone).

5.3. The Need for Wireless

UAVs cannot be connected through any type of wired media, so it is obvious that wireless is needed.

5.4. Asks for SPAWN

The network infrastructure is actually composed by the UAVs themselves, requiring self-configuration capabilities.

Heterogeneous types of traffic need to be supported, from extremely critical ones requiring ultra low latency and high resiliency, to traffic requiring low-medium latency.

When a given service is decomposed into functions -- hosted at different drones -- chained, each link connecting two given functions would have a well-defined set of requirements (latency, bandwith and jitter) that have to be met.

6. Edge Robotics control

6.1. Use Case Description

The Edge Robotics scenario consists of several robots, deployed in a given area (for example a shopping mall), inter-connected via an access network to a network's edge device or a data center. The robots are connected to the edge so complex computational activities are not executed locally at the robots, but offloaded to the edge. This brings additional flexibility in the type of tasks that the robots do, as well as reducing the costs of robot manufacturing (due to their lower complexity), and enabling complex tasks involving coordination among robots (that can be more easily performed if robots are centrally controlled).

A simple example of the use of multiples robots is cleaning,

delivering of goods from warehouses to shops or video surveillance. Multiple robots are simultaneously instructed to perform individual tasks by moving the robotic intelligence from the robots to the network's edge (e.g., data center). That enables easy synchronization, scalable solution and on-demand option to create flexible fleet of robots.

Robots would have various forms of wireless connectivity:

- o IEEE 802.11: for connection to the edge and also inter-robot communications (e.g., for coordinated actions);
- o cellular: as an additional communication link to the edge, though primarily as backup, since ultra low latencies are needed.

6.2. Specificities

Some of the use cases/tasks involving robots might benefit from decomposition of a service in small functions that are distributed and chained among robots and the edge. These require continuous connectivity with the control center and among drones.

Robot control is an activity requiring very low latencies between the robot and the location where the control intelligence resides (which might be the edge or another robot).

6.3. The Need for Wireless

Deploying robots in scenarios such as shopping malls for the aforementioned applications cannot be done via wired connectivity.

6.4. Asks for SPAWN

The network infrastructure needs to support heterogeneous types of traffic, from robot control to video streaming.

When a given service is decomposed into functions -- hosted at different robots -- chained, each link connecting two given functions would have a well-defined set of requirements (latency, bandwith and jitter) that have to be met.

7. IANA Considerations

TBD.

8. Security Considerations

TBD.

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