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RAW 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 wireless use cases demanding reliable and available behavior.

Status of This Memo

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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,
- multi-technology path with co-channel interference minimization,
- frame preemption and guard time mechanisms to ensure a worst-case delay, 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. RAW (Reliable and Available Wireless) is an effort to provide Deterministic Networking Mechanisms on across a path that include a wireless physical layer. Making Wireless Reliable and Available is even more challenging than it is with wires, due to the numerous causes of loss in transmission that add up to the congestion losses and the delays caused by overbooked shared resources.

The wireless and wired media are fundamentally different at the physical level, and while the generic Problem Statement [RFC8557] for DetNet applies to the wired as well as the wireless medium, the methods to achieve RAW 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 [RFC8655] 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 developped 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 [I-D.thubert-raw-technologies]:

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

- IEEE 802.11 has identified a set of real-applications [ieee80211-rt-tig] which may use the IEEE802.11 standards. They typically emphasize strict end-to-end delay requirements.

- 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 Reliable and Available Wireless (RAW) on a shared MAC.

This draft extends the "Deterministic Networking Use Cases" document [RFC8578] and describes a number of additional use cases which require "reliable/predictable and available" flows over wireless links and possibly complex multi-hop paths called Tracks. This is

covered mainly by the "Wireless for Industrial Applications" use case, as the "Cellular Radio" is mostly dedicated to the (wired) transport part of a Radio Access Network (RAN). Whereas the "Wireless for Industrial Applications" use case certainly covers an area of interest for RAW, it is limited to 6TiSCH, and thus its scope is narrower than the use cases described next in this document.

2. Aeronautical Communications

Aircraft are currently connected to ATC (Air-Traffic Control) and AOC (Airline Operational Control) via voice and data communications systems through all phases of a flight. Within the airport terminal, connectivity is focused on high bandwidth communications while during en-route high reliability, robustness and range is the main focus.

2.1. Problem Statement

Up to 2020 civil air traffic has been growing constantly at a compound rate of 5.8% per year [ACI19] and despite the severe impact of the COVID-19 pandemic, air traffic growth is expected to resume very quickly in post-pandemic times [IAT20] [IAC20]. Thus, legacy systems in air traffic management (ATM) are likely to reach their capacity limits and the need for new aeronautical communication technologies becomes apparent. Especially problematic is the saturation of VHF band in high density areas in Europe, the US, and Asia [KEAV20] [FAA20] calling for suitable new digital approaches such as AeroMACS for airport communications, SatCOM for remote domains, and LDACS as long-range terrestrial aeronautical communications system. Making the frequency spectrum's usage more efficient a transition from analogue voice to digital data communication [PLA14] is necessary to cope with the expected growth of civil aviation and its supporting infrastructure. A promising candidate for long range terrestrial communications, already in the process of being standardized in the International Civil Aviation Organization (ICAO), is the L-band Digital Aeronautical Communications System (LDACS) [ICAO18] [I-D.ietf-raw-ldacs].

2.2. Specifics

During the creation process of new communications system, analogue voice is replaced by digital data communication. This sets a paradigm shift from analogue to digital wireless communications and supports the related trend towards increased autonomous data processing that the Future Communications Infrastructure (FCI) in civil aviation must provide. The FCI is depicted in Figure 1:

```
    Satellite
   #         #
   #          # #
   #            #   #
   #             #      #
   #               #        #
   #                #          #
   #                  #            #
   # Satellite-based   #              #
   #   Communications   #                 #
   #      SatCOM (#)     #                   #
   #                      #                    Aircraft
   #                       #                 %         %
   #                        #              %             %
   #                         #           %     Air-Air     %
   #                          #        %     Communications   %
   #                           #     %         LDACS A/A (%)    %
   #                           #   %                              %
   #                            Aircraft  % % % % % % % % % %  Aircraft
   #                                 |           Air-Ground           |
   #                                 |         Communications         |
   #                                 |           LDACS A/G (|)        |
   #      Communications in          |                                |
   #    and around airports          |                                |
   #         AeroMACS (-)            |                                |
   #                                 |                                |
   #         Aircraft-------------+  |                                |
   #                              |  |                                |
   #                              |  |                                |
   #         Ground network       |  |         Ground network         |
   SatCOM <---------------------> Airport <----------------------> LDACS
   transceiver                     based                             GS
   transceiver
```

Figure 1: The Future Communication Infrastructure (FCI): AeroMACS for APT/TMA domain, LDACS A/G for TMA/ENR domain, LDACS A/G for ENR/ORP domain, SatCOM for ORP domain communications

2.3. Challenges

This paradigm change brings a lot of new challenges:

- Efficiency: It is necessary to keep latency, time and data overhead (routing, security) of new aeronautical datalinks at a minimum.

- o Modularity: Systems in avionics usually operate up to 30 years, thus solutions must be modular, easily adaptable and updatable.

- o Interoperability: All 192 members of the international Civil Aviation Organization (ICAO) must be able to use these solutions.

2.4. The Need for Wireless

In a high mobility environment such as aviation, the envisioned solutions to provide worldwide coverage of data connections with in-flight aircraft require a multi-system, multi-link, multi-hop approach. Thus air, ground and space-based datalink providing technologies will have to operate seamlessly together to cope with the increasing needs of data exchange between aircraft, air traffic controller, airport infrastructure, airlines, air network service providers (ANSPs) and so forth. Thus, making use of wireless technologies is a MUST in tackling this enormous need for a worldwide digital aeronautical datalink infrastructure.

2.5. Requirements for RAW

Different safety levels need to be supported, from extremely safety critical ones requiring low latency, such as a WAKE warning - a warning that two aircraft come dangerously close to each other - and high resiliency, to less safety critical ones requiring low-medium latency for services such as WXGRAPH - graphical weather data.

Overhead needs to be kept at a minimum since aeronautical data links provide comparatively small data rates in the order of kbit/s.

Policy needs to be supported when selecting data links. The focus of RAW here should be on the selectors, responsible for the routing path a packet takes to reach its end destination. This would minimize the amount of routing information that has to travel inside the network because of precomputed routing tables with the selector being responsible for choosing the most appropriate option according to policy and safety.

3. Amusement Parks

3.1. Use Case Description

The digitalization of Amusement Parks is expected to decrease significantly the cost for maintaining the attractions. Such deployment is a mix between industrial automation (aka. Smart Factories) and multimedia entertainment applications.

Attractions may rely on a large set of sensors and actuators, which react in real time. Typical applications comprise:

o Emergency: safety has to be preserved, and must stop the attraction when a failure is detected.

o Video: augmented and virtual realities are integrated in the attraction. Wearable mobile devices (e.g., glasses, virtual reality headset) need to offload one part of the processing tasks.

o Real-time interactions: visitors may interact with an attraction, like in a real-time video game. The visitors may virtually interact with their environment, triggering actions in the real world (through actuators) [robots].

o Geolocation: visitors are tracked with a personal wireless tag so that their user experience is improved.

o 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.

3.2. Specifics

Amusement parks comprise a variable number of attractions, mostly outdoor, over a large geographical area. The IT infrastructure is typically multi-scale:

o Local area: the sensors and actuators controlling the attractions are co-located. Control loops trigger only local traffic, with a small end-to-end delay, typically inferior than 10 milliseconds, like classical industrial systems [ieee80211-rt-tig].

o Wearable mobile devices are free to move in the park. They exchange traffic locally (identification, personalization, multimedia) or globally (billing, child tracking).

o Computationally intensive applications offload some tasks. Edge computing seems an efficient way to implement real-time applications with offloading. Some non time-critical tasks may rather use the cloud (predictive maintenance, marketing).

3.3. The Need for Wireless

Amusement parks cover large areas and a global interconnection would require a huge length of cables. Wireless also increases the reconfigurability, enabling to update cheaply the attractions. The frequent renewal helps to increase customer loyalty.

Some parts of the attraction are mobile, e.g., trucks of a roller-coaster, robots. Since cables are prone to frequent failures in this situation, wireless transmissions are recommended.

Wearable devices are extensively used for a user experience personalization. They typically need to support wireless transmissions. Personal tags may help to reduce the operating costs [disney-VIP] and to increase the number of charged services provided to the audience (VIP tickets, interactivity, etc.) Some applications rely on more sophisticated wearable devices such as digital glasses or Virtual Reality (VR) headsets for an immersive experience.

3.4. Requirements for RAW

The network infrastructure has to support heterogeneous traffic, with very different critical requirements. Thus, flow isolation has to be provided.

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, we still need multi-technology solutions, able to guarantee end-to-end requirements across heterogeneous technologies, with strict SLA requirements.

Nowadays, long-range wireless transmissions are used mostly for best-effort traffic. On the contrary, [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 layers.

We expect to deploy several different technologies (long vs. short range) which have to cohabit in the same area. Thus, we need to provide layer-3 mechanisms able to exploit multiple co-interfering technologies.

4. Wireless for Industrial Applications

4.1. Use Case Description

A major use case for networking in Industrial environments 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 (PLC) 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.

4.2. Specifics

4.2.1. Control Loops

Process Control designates continuous 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 reliably 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.

4.2.2. 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.

4.3. 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 4.2.1). 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.

4.4. Requirements for RAW

As stated by the "Deterministic Networking Problem Statement" [RFC8557], 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. RAW 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. RAW mechanisms 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. It is also important to ensure that RAW solutions are interoperable with existing wireless solutions in place, and with legacy equipment which

capabilities can be extended using retrofitting. Maintanability, as a broader concept than reliability is also important in industrial scenarios [square-peg].

5. Pro Audio and Video

5.1. Use Case Description

Many devices support audio and video streaming by employing 802.11 wireless LAN. Some of these applications require low latency capability. For instance, when the application provides interactive play, or when the audio takes plays in real time (i.e. live) for public addresses in train stations or in theme parks.

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

- o Virtual Reality / Augmented Reality (VR/AR)

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

5.2. Specifics

5.2.1. Uninterrupted Stream Playback

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. Buffering might be employed to provide a certain delay which will allow for one or more re-transmissions, however such approach is not efficient in application where delays are not acceptable.

5.2.2. Synchronized Stream Playback

In the context of ProAV, latency is the time between the transmitted signal over a stream and its reception. Thus, for sound to remain synchronized to the movement in the video, the latency of both the audio and video streams must be bounded and consistent.

5.3. The Need for Wireless

The devices need the wireless communication to support video streaming via 802.11 wireless LAN for instance.

During the public address, the deployed announcement speakers, for instance along the platforms of the train stations, need the wireless communication to forward the audio traffic in real time.

5.4. Requirements for RAW

The network infrastructure needs to support heterogeneous types of traffic (including QoS).

Content delivery with bounded (lowest possible) latency.

The deployed network topology should allow for multipath. This will enable for multiple streams to have different (and multiple) paths through the network to support redundancy.

6. Wireless Gaming

6.1. Use Case Description

The gaming industry includes [IEEE80211RTA] real-time mobile gaming, wireless console gaming and cloud gaming. For RAW, wireless console gaming is the most relevant one. We next summarize the three:

- Real-time Mobile Gaming: Different from traditional games, real time mobile gaming is very sensitive to network latency and stability. The mobile game can connect multiple players together in a single game session and exchange data messages between game server and connected players. Real-time means the feedback should present on screen as users operate in game. For good game experience, the end to end latency plus game servers processing time should not be noticed by users as they play the game.

- Wireless Console Gaming: Playing online on a console has 2 types of internet connectivity, which is either wired or Wi-Fi. Most of the gaming consoles today support Wi-Fi 5. But Wi-Fi has an especially bad reputation among the gaming community. The main reasons are high latency, lag spikes and jitter.

- Cloud Gaming: The cloud gaming requires low latency capability as the user commands in a game session need to be sent back to the cloud server, the cloud server would update game context depending on the received commands, and the cloud server would render the picture/video to be displayed at user devices and stream the picture/video content to the user devices. User devices might very likely be connected wirelessly.

6.2. Specifics

While a lot of details can be found on [IEEE80211RTA], we next summarize the main requirements in terms of latency, jitter and packet loss:

- Intra BSS latency: less than 5 ms.

- Jitter variance: less than 2 ms.

- Packet loss: less than 0.1 percent.

6.3. The Need for Wireless

It is clear that gaming is evolving towards wireless, as players demand being able to play anywhere. Besides, the industry is changing towards playing from mobile phones, which are inherently connected via wireless technologies.

6.4. Requirements for RAW

- Time sensitive networking extensions. Extensions, such as time-aware shaping and redundancy (FRE) can be explored to address congestion and reliability problems present in wireless networks.

- Priority tagging (Stream identification). One basic requirement to provide better QoS for time-sensitive traffic is the capability to identify and differentiate time-sensitive packets from other (e.g. best-effort) traffic.

- Time-aware shaping. This capability (defined in IEEE 802.1Qbv) consists of gates to control the opening/closing of queues that share a common egress port within an Ethernet switch. A scheduler defines the times when each queue opens or close, therefore eliminating congestion and ensuring that frames are delivered within the expected latency bounds.

- Dual/multiple link. Due to the competitions and interference are common and hardly in control under wireless network, in order to improve the latency stability, dual/multiple link proposal is brought up to address this issue. Two modes are defined: duplicate and joint.

- Admission Control. Congestion is a major cause of high/variable latency and it is well known that if the traffic load exceeds the capability of the link, QoS will be degraded. QoS degradation maybe acceptable for many applications today, however emerging time-sensitive applications are highly susceptible to increased

latency and jitter. In order to better control QoS, it is important to control access to the network resources.

7. UAV platooning and control

7.1. 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 maneuvering as well as monitoring of the drone;

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

7.2. Specifics

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 cased, however, there are situations that need very low latencies and deterministic behavior of the connectivity. Examples involve platooning of drones or share of computing resources among drones (e.g., a drone offload some function to a neighboring drone).

7.3. The Need for Wireless

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

7.4. Requirements for RAW

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, bandwidth and jitter) that have to be met.

8. Edge Robotics control

8.1. 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.

8.2. Specifics

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).

8.3. The Need for Wireless

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

8.4. Requirements for RAW

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, bandwidth and jitter) that have to be met.

9. Emergencies: Instrumented emergency vehicle

9.1. Use Case Description

An instrumented ambulance would be one that has a LAN to which are connected these end systems:

- o vital signs sensors attached to the casualty in the ambulance. Relay medical data to hospital emergency room,
- o radionavigation sensor to relay position data to various destinations including dispatcher,
- o voice communication for ambulance attendant (e.g. consult with ER doctor),
- o voice communication between driver and dispatcher,
- o etc.

The LAN needs to be routed through radio-WANs to complete the internetwork linkage.

9.2. Specifics

What we have today is multiple communications systems to reach the vehicle:

- A dispatching system,
- a cellphone for the attendant,
- a special purpose telemetering system for medical data,
- etc.

This redundancy of systems, because of its stovepiping, does not contribute to availability as a whole.

Most of the scenarios involving the use of an instrumented ambulance are composed of many different flows, each of them with slightly different requirements in terms of reliability and latency. Destinations might be either at the ambulance itself (local traffic), at a near edge cloud or at the general Internet/cloud.

9.3. The Need for Wireless

Local traffic between the first responders/ambulance staff and the ambulance equipment cannot be doine via wireled connectivity as the responders perform initial treatment outside of the ambulance. The communications from the ambulance to external services has to be wireless as well.

9.4. Requirements for RAW

We can derive some pertinent requirements from this scenario:

- High availability of the internetwork is required.
- The internetwork needs to operate in damaged state (e.g. during an earthquake aftermath, heavy weather, wildfire, etc.). In addition to continuity of operations, rapid restoral is a needed characteristic.
- End-to-end security, both authenticity and confidentiality, is required of traffic. All data needs to be authenticated; some (such as medical) needs to be confidential.
- The radio-WAN has characteristics similar to cellphone -- the vehicle will travel from one radio footprint to another.

10. IANA Considerations

This document has no IANA actions.

11. Security Considerations

This document covers a number of representative applications and network scenarios that are expected to make use of RAW technologies. Each of the potential RAW use cases will have security considerations from both the use-specific perspective and the RAW technology perspective. [I-D.ietf-detnet-security] provides a comprehensive discussion of security considerations in the context of Deterministic Networking, which are generally applicable also to RAW.

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