Reliable and Available Wireless Problem Statement
draft-pthubert-raw-problem-statement-00

Abstract

This document describes the problem space for Reliable and Available Wireless at the IETF.

Table of Contents

1. Introduction

IP networks become more predictable when the effects of statistical multiplexing (jitter and collision loss) are 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.

Deterministic Networking is an attempt to mostly eliminate packet loss for a committed bandwidth with a guaranteed worst-case end-to-end latency, even when co-existing with best-effort traffic in a shared network. It is getting traction in various industries including manufacturing, online gaming, professional A/V, cellular radio and others, making possible many cost and performance optimizations.

This innovation is enabled by recent developments in technologies including IEEE 802.1 TSN (for Ethernet LANs) and IETF DetNet (for wired IP networks). Reliable and Available Wireless (RAW) networking services extend DetNet services to approach end-to-end deterministic performances in a network with scheduled wireless segments, possibly combined with wired segments, and possibly sharing physical resources with non-deterministic traffic.

Wireless networks operate on a shared medium, and thus transmissions cannot be fully deterministic due to uncontrolled interferences, including the self-induced multipath fading. However, scheduling of transmissions can alleviate those effects by leveraging diversity in the spatial, time and frequency domains, providing a more predictable and available service.

The wireless and wired media are fundamentally different at the physical level, and while the generic Problem Statement for DetNet applies to the wired as well as the wireless medium, the methods to

achieve RAW will differ from those used to support time-sensitive networking over wires, and a RAW solution will need to address less consistent transmissions, energy conservation and shared spectrum efficiency.

The development of RAW technologies has been lagging behind deterministic efforts for wired systems both at the IEEE and the IETF. But recent efforts at the IEEE and 3GPP indicate that wireless is finally catching up at the lower layer and that it is now possible for the IETF to extend DetNet for wireless segments that are capable of scheduled wireless transmissions.

The establishment of the path is out of scope, and may inherit from a centralized Architecture as described for DetNet and 6TiSCH, with a primary focus on scheduled wireless operations. As opposed to wire, the action of setting up a path on a wireless network may be slow compared to the speed at which the transmission conditions vary, and the extra medium used for redundancy may be expensive. So in wireless, it makes sense for a centralized router to provide multiple forwarding solutions and leave it to the data plane to select which of those solutions are used fir a given packet based on the current conditions.

The scope of the RAW WG will be protocol elements such as OAM to improve the forwarding decision along a path where intermediate nodes are capable of transmission redundancy, e.g., using packet replication and elimination, Hybrid ARQ and coding, but is constrained so as not to overuse this methods, eg., because energy and spectrum are limited.

RAW should stay abstract to the radio layer (keep a layered approach). How the PHY is programmed, and whether the radio is single-hop or meshed, are unknown at the IP layer and not part of the RAW abstraction.

Still, in order to focus on real-worlds issues and assert the feasibility of the proposed capabilities, RAW will focus on selected technologies that can be scheduled at the lower layers: IEEE Std. 802.15.4 timeslotted channel hopping (TSCH), 3GPP 5G ultra-reliable low latency communications (URLLC), IEEE 802.11ax/be where 802.11be is extreme high throughput (EHT), and L-band Digital Aeronautical Communications System (LDACS). See [I-D.thubert-raw-technologies] for more.

RAW distinguishes the time scale at which routes are computed that we qualify as slow from the forwarding time scale where per-packet decisions are made. RAW operates at the forwarding time scale on one DetNet flow over one Track that is preestablished and installed by

means outside of the scope of RAW. This is discussed in more details in Section 3 and the next sections.

2. Use Cases and Requirements Served

[RFC8578] presents a number of wireless use cases including Wireless for Industrial Applications. [I-D.bernardos-raw-use-cases] adds a number of use cases that demonstrate the need for RAW capabilities in Pro-Audio, gaming and robotics.

3. Routing Scale vs. Forwarding Scale

RAW extends DetNet to focus on issues that are mostly a concern on wireless links. See [I-D.ietf-detnet-architecture] for more on DetNet. With DetNet, the end-to-end routing can be centralized and can reside outside the network. In wireless, and in particular in a wireless mesh, the path to the controller that performs the route computation and maintenance may be slow and expensive in terms of critical resources such as air time and energy.

Reaching to the routing computation can be slow in regards to the speed of events that affect the forwarding operation at the radio layer. Due to the cost and latency to perform a route computation, routing is not expected to be sensitive/reactive to transient changes. The abstraction of a link at the routing level is expected to use statistical operational metrics that aggregate the behavior of a link over long periods of time, and represent its availability as a shade of gray as opposed to either up or down.

In the case of wireless, the changes that affect the forwarding decision can happen frequently and often for shot durations, e.g., a mobile object moves between a transmitter and a receiver, and will cancel the line of sight transmission for a few seconds, or a radar measures the depth of a pool and interferes on a particular channel for a split second.

There is thus a desire to separate the long term computation of the route and the short term forwarding decision. In such a model, the routing operation computes a complex Track that enables multiple non-equal cost multipath (N-ECMP) forwarding solutions, and leaves it to the forwarding plane to make the per-packet decision of which of these possibilities should be used.

In the case of wires, the concept is known in traffic engineering where an alternate path can be used upon the detection of a failure in the main path, e.g., using OAM in MPLS-TP or BFD over a collection of SD-WAN tunnels. RAW formalizes a routing time scale that is order of magnitude longer than the forwarding time scale, and separates the

protocols and metrics that are used at both scales. Routing can operate on long term statistics such as delivery ratio over minutes to hours, but as a first approximation can ignore flapping. On the other hand, the RAW forwarding decision is made at packet speed, and uses information that must be pertinent at the present time for the current transmission.

4. Prerequisites

A prerequisite to the RAW work is that an end-to-end routing function computes a complex sub-topology along which forwarding can happen between a source and one or more destinations. For 6TiSCH, this is a Track. The concept of Track is specified in the [I-D.ietf-6tisch-architecture]. Tracks provide a high degree of redundancy and diversity and enable DetNet PREOF, end-to-end network coding, and possibly radio-specific abstracted techniques such as ARQ, overhearing, frequency diversity, time slotting, and possibly others.

How the routing operation computes the Track is out of scope for RAW. The scope of the RAW operation is one Track, and the goal of the RAW operation is to optimize the use of the Track at the forwarding timescale to maintain the expected service while optimizing the usage of constrained resources such as energy and spectrum.

Another prerequisite is that an IP link can be established over the radio with some guarantees in terms of service reliability, e.g., it can be relied upon to transmit a packet within a bounded latency and provides a guaranteed BER/PDR outside rare but existing transient outage windows that can last from split seconds to minutes. The radio layer can be programmed with abstract parameters, and can return an abstract view of the state of the Link to help forwarding decision (think DLEP from MANET). In the layered approach, how the radio manages its PHY layer is out of control and out of scope. Whether it is single hop or meshed is also unknown and out of scope.

5. Functional Gaps

Within a large routed topology, the routing operation builds a particular complex Track with one source and one or more destinations; within the Track, packets may follows different paths and may be subject to RAW forwarding operations that include replication, elimination, retries, overhearing and reordering.

The RAW forwarding decisions include the selection of points of replication and elimination, how many retries can take place, and cccccckehblnlcbljtkbcdkrhrjgiibvcidbklbglndf a limit of validity for

the packet beyond which the packet should be destroyed rather than forwarded uselessly further down the Track.

The decision to apply the RAW techniques must be done quickly, and depends on a very recent and precise knowledge of the forwarding conditions withing the complex Track. There is a need for an observation method to provide the RAW forwarding plane with the specific knowledge of the state of the Track for the type of flow of interest (e.g., for a QoS level of interest). To observe the whole Track in quasi real time, RAW will consider existing tools such as L2-triggers, DLEP, BFD and inband and out-of-band OAM.

One possible way of making the RAW forwarding decisions is to make them all at the ingress and express them in-band in the packet, which requires new loose or strict Hop-by-hop signaling. To control the RAW forwarding operation along a Track for the individual packets, RAW may leverage and extend known techniques such as Segment Routing (SRv6) or BIER-TE such as done with [I-D.thubert-bier-replication-elimination].

An alternate way is to enable each forwarding node to make the RAW forwarding decisions for a packet on its own, based on its knowledge of the expectation (timeliness and reliability) for that packet and a recent observation of the rest of the way across the possible paths within the Track. Information about the service should be placed in the packet and matched with the forwarding node's capabilities and policies.

In either case, a per-flow state is installed in all intermediate nodes to recognize the flow and determine the forwarding policy to be applied.

6. References

6.1. Normative References

[I-D.bernardos-raw-use-cases]
Papadopoulos, G., Thubert, P., Theoleyre, F., and C. Bernardos, "RAW use cases", draft-bernardos-raw-use-cases-00 (work in progress), July 2019.

[I-D.ietf-6tisch-architecture]
Thubert, P., "An Architecture for IPv6 over the TSCH mode of IEEE 802.15.4", draft-ietf-6tisch-architecture-26 (work in progress), August 2019.

[I-D.ietf-detnet-architecture]
Finn, N., Thubert, P., Varga, B., and J. Farkas, "Deterministic Networking Architecture", draft-ietf-detnet-architecture-13 (work in progress), May 2019.

[I-D.thubert-raw-technologies]
Thubert, P., Cavalcanti, D., Vilajosana, X., and C. Schmitt, "Reliable and Available Wireless Technologies", draft-thubert-raw-technologies-03 (work in progress), July 2019.

[RFC8578] Grossman, E., Ed., "Deterministic Networking Use Cases", RFC 8578, DOI 10.17487/RFC8578, May 2019, <https://www.rfc-editor.org/info/rfc8578>.

6.2. Informative References

[CCAMP] IETF, "Common Control and Measurement Plane", <https://dataTracker.ietf.org/doc/charter-ietf-ccamp/>.

[I-D.thubert-bier-replication-elimination]
Thubert, P., Eckert, T., Brodard, Z., and H. Jiang, "BIER-TE extensions for Packet Replication and Elimination Function (PREF) and OAM", draft-thubert-bier-replication-elimination-03 (work in progress), March 2018.

[PCE] IETF, "Path Computation Element", <https://dataTracker.ietf.org/doc/charter-ietf-pce/>.

[TEAS] IETF, "Traffic Engineering Architecture and Signaling", <https://dataTracker.ietf.org/doc/charter-ietf-teas/>.

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