Your Message Rescues Me: Enhancing NDN Communication Quality in Disaster Scenarios

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ABSTRACT

This demo showcases how ICN resource management can service the needs of very challenged deployments such as constrained IoT edge networks in disaster scenarios. Using realistic implementations on RIOT, we demonstrate how very constrained devices in harsh environments can reliably communicate, provided QoS measures are in place. These devices gradually invoke traffic flows of different priority levels, which are displayed in real-time on a dashboard. In this setup, we contrast regular bulk traffic with degradation in flow latency and reliability with QoS-enhanced traffic differentiation and visualize the improved flow resource consumption of high priority traffic on all nodes.

CCS CONCEPTS

• **Networks → Network design principles**; *Naming and addressing*; • **Computer systems organization → Sensor networks**; *Embedded and cyber-physical systems.*

KEYWORDS

Internet of Things; Information Centric Networks; QoS

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1 INTRODUCTION

ICN has been a promising candidate for networking the IoT edge for a while. Recent experimental studies [3, 4] confirmed that ICN can sustain high reliability at moderate timing even in wireless low-power and lossy networks (LLNs), and showed how it could be integrated into the 5G edge architecture. However, current analyses and solutions are built purely on equal resource sharing. In the last two decades, various Quality of Service (QoS) approaches emerged for IP networks, but a plain transitioning of these concepts to ICN remains questionable. While previous QoS mechanisms purely restrict on managing forwarding resources, such as link capacities and buffer spaces, ICN offers additional resource dimensions in terms of in-network caches and forwarding states that can shape the network performance significantly.

In the remainder of this document, we motivate the need for constrained NDN [6] networks with QoS mechanisms in hazardous and life-threatening disaster scenarios (§ 2), and present an implementation of a lightweight QoS management for constrained NDN networks using real IoT devices and two traffic flow patterns of distinct priority levels (§ 3).

2 USE CASE

Challenges in Disaster Scenarios. In natural or man-made disasters a quick response is imperative to prevent extensive harm to people, the environment, and to minimize collateral damage. With this objective, first responders are sent into the field to (i) assess the situation on-site, (ii) to immediately apply first aid, and (3) to call for appropriate further emergency support.

For an efficient operation, search and rescue forces require operational guidance by command & control centers. Since flawless operations of on-site and pre-existing network infrastructures are usually inhibited by disasters, rescue forces are compelled to spontaneously unroll radio-based, mobile networks to handle traffic flows of different importance under intermittent connectivity.

Typically, hand-held communication devices are attached to field units and report back sensor readings of several sensors that are deployed in the equipment and the immediate vicinity. Sensor devices are battery-operated with a small form factor in order to not interfere with the mobility and maneuverability of rescuers. With such requirements on hand, sensors display constraints [2] in memory, processing power and energy resources.

Networking Requirements. In disaster scenarios, networked sensor devices usually form an LLN, where device limitations can significantly impact the overall network performance. To mitigate performance degradations for continuous and life-critical traffic flows, such as ECG heartbeat monitoring, the network must be able to differentiate traffic flows, become aware of flow-based priorities, and has to balance available resources accordingly to flow priorities.

NDN deployments have shown great potential to successfully operate in disaster scenarios [7] by naturally providing in-network caches, supporting consumer mobility, and by its intrinsic multicast capability. Unlike in IP networks, NDN utilizes a stateful forwarding

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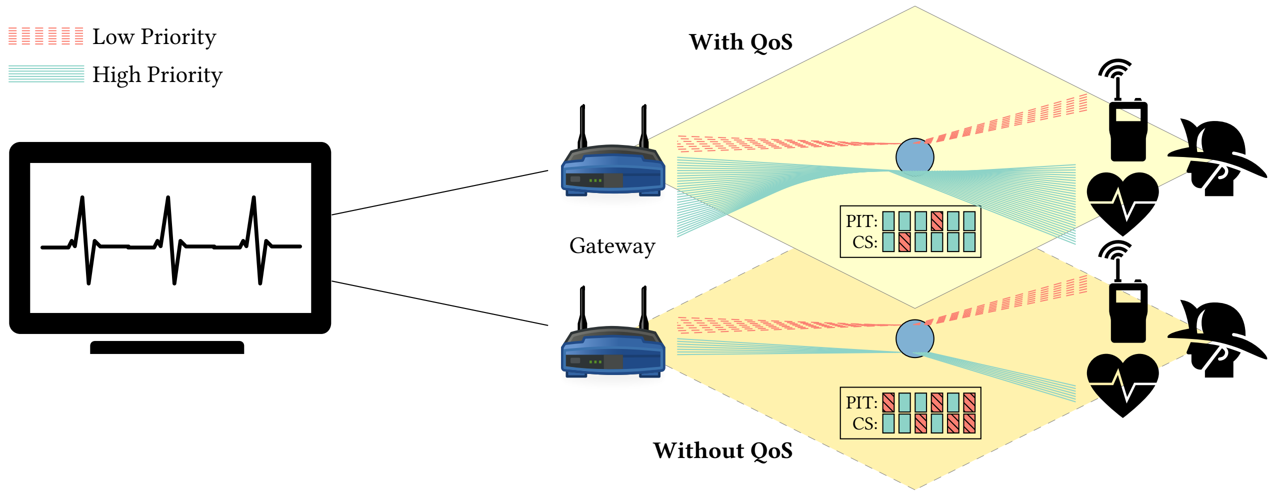

Figure 1: Resource allocation with and without QoS mechanisms in a disaster scenario.

fabric that allocates resources per request-response flow on each hop. NDN introduces open request state and in-network cache space as manageable resources. Consequently, the most apparent manageable resources to be governed by a QoS management system are (i) link layer forwarding and queuing, (ii) *Pending Interest Table (PIT)* state, and (iii) *Content Store (CS)* space.

3 DEMO SETUP AND DESCRIPTION

Scenario. We look at a disaster scenario where a spontaneous network is set up to assist search and rescue forces. We invoke two traffic flows in order to (1) monitor the heartbeat of rescuers, and (2) to dispatch operational audio messages to field units using hand-held communication devices.

Hardware and Software Platform. In our demo, we deploy three battery-operated devices that feature an ARM Cortex-M4 MCU with 32 kB RAM and 256 kB ROM. A heartbeat sensor acts as producer, a communication device as consumer and a third device as forwarder. We enforce a multi-hop topology using link layer address filtering. All devices mount an RGB LED bar to display the current PIT state. We assign different colors to each flow in order to easily quantify the effects of resource sharing mechanisms on the forwarder device.

Our gateway runs Raspbian *Buster* and our IoT devices operate the latest RIOT [1] version *2019.07*. We use CCN-lite [8] as NDN network stack and extend it to include the lightweight QoS management for constrained NDN networks [5].

Demo Description. Figure 1 illustrates the general setup for two configurations: with and without QoS features enabled. In the initial setup, we deploy our scenario with QoS features disabled. Our gateway continuously requests heartbeat sensor readings and displays them on a dashboard. In addition, our communication device polls new audio messages every 10 seconds to receive up to date fireground assistance. Once an audio message exists, the message is bulk requested, thereby leading to resource saturation on the forwarder and a disruption of continuous heartbeat readings on the gateway. We repeat this setup with QoS features enabled and assign a high prioritization to the heartbeat flow. On the dashboard, we illustrate an uninterrupted heartbeat signal to indicate the low latency and high reliability characteristics of our prioritized traffic flow, while slightly distorted audio messages are still being dispatched to our communication device on the fireground.

4 FUTURE WORK

In future work, we want to explore further correlations between PIT and CS placement strategies to promote low latencies, improve cache diversity and enhance reliability. An experimental deployment in our industrial environment is also on schedule.

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