Evaluation of Path States of Large IoT Networks Using Locally and Remotely Controlled Measurements

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***Abstract*—The state of network paths is of great importance for the quality and reliability of the transmission of information coming from the IoT devices. Changing network conditions cause the state of a single path to be highly unpredictable, especially when large-scale IoT networks, connecting thousands of specialized devices, are in use. The solution to this problem is to perform trials in a real environment, with the use of real hardware. The rationalization of the design, the implementation and the exploitation of the process will be the main benefit of this approach.**

In this demonstration, a testbed infrastructure for the estimation of the state of path parameters in wired and wireless networks is presented. The estimation is based mainly on active measurements performed with the use of the Probing Packet Trains method. The key elements of the testbed infrastructure are locally and remotely controlled energy-efficient single-board computers, working under the control of the Linux operating system, which are equipped with software able to track (in manual or automatic mode) changing conditions of a given transmission path.

Keywords—congestion control, Internet of Things, measurements, Probing Packet Trains

I. Introduction

The rapid growth of the use of Internet of Things (IoT) devices (Cisco predicts there will be 14.7 billion of IoT devices connected to the Internet by 2023) in Industry 4.0, intelligent buildings, smart cities, etc., is a great challenge for designers and deployers. Services based on IoT devices are only as good as the quality (i.e. sure and actual) of data obtained from and delivered to the IoT devices. Data delivery to and from IoT devices strictly depends on network conditions, which, in turn, depends on the characteristics of the transmitted traffic. Behavioral differences of traffic sources, congestion growing in nearby large traffic hubs which cannot be unloaded by classic congestion control mechanisms, and other observable disadvantages cause the network condition to vary in time. As a result, the state of the path between an IoT source and its destination point is hard to predict, and the importance of the observation and acquisition of empirical data increases.

This puts large IoT systems as the potential subject of interest for other IoT systems that monitor the state of single links or whole transmission paths inside IoT networks and provide measurements aimed to gain detailed knowledge about current network conditions. As was reported in [1][2], design, development and exploitation of IoT-based systems should be connected with measurements of IoT traffic.

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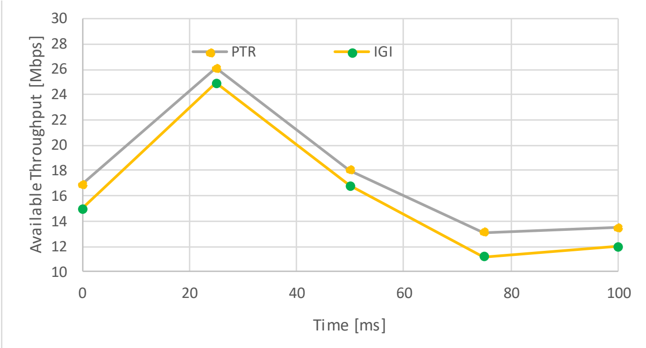

Fig. 1. Differences between estimations of instantaneous available bandwidth coming from PTR and IGI variants of the PPT method.

II. Demo Description

In this demonstration, the results of measurements carried out in a scalable IoT network are presented. Figure 3 outlines the functional building of the evaluated network and highlights the main elements of the testbed.

Measurements, which are the key point of each evaluation, were performed using mature versions of custom designed IoT measuring devices. The first prototype of our device, originally intended for manual and automated estimation of link occupancy, was presented at the conference [3] and then described in the journal [4]. However, the used this method of estimation, based on Probing Packet Trains [5], allows this device to be used for a more general application, such as the estimation of the general state of the transmission path from our measurer to a given destination point.

During the demonstration, the following features of the presented IoT device are shown:

- **Probing Packet Trains method.** This is one of the main measurement methods used during the path state estimation. This is an active measuring method, which consists of the injection of a series of packets into a network with these packets being subsequently echoed by the other end point of the investigated path. The PPT method was implemented in two high-speed, energy-efficient variants: Packet Transmission Rate (PTR) and Initial Gap Increasing (IGI). The comparison of these variants, performed on the example of the estimation of available bandwidth of the currently used path, is shown in Fig. 1.

- **Estimation of the state of the transmission path.** In particular, estimation of the available bandwidth (bit

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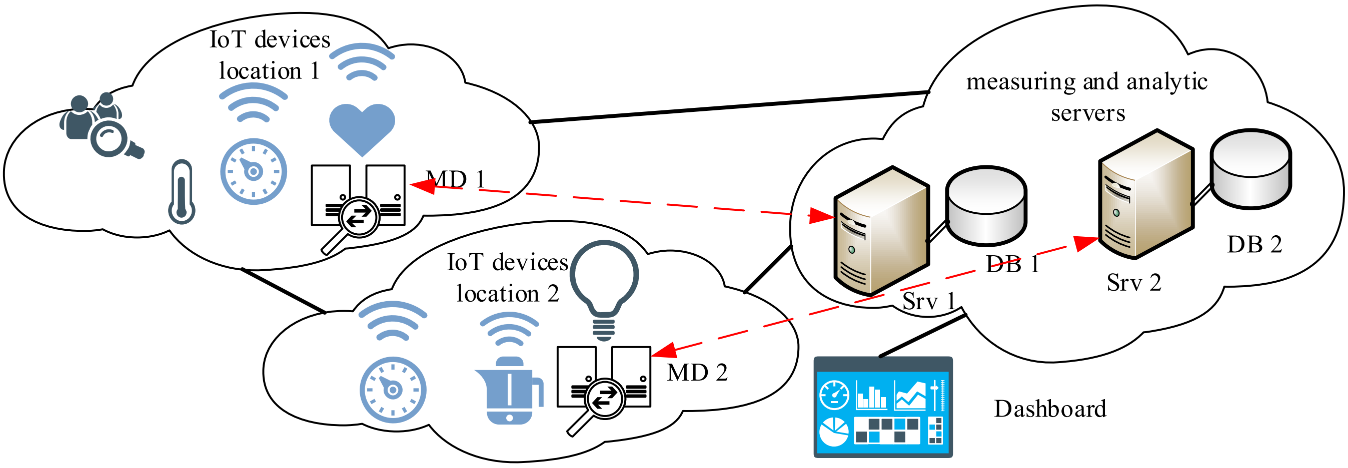

Fig. 2. Overview of the demonstrated testbed. Path state measurers are attached to subnetworks of the test network, and measuring servers are located in the private computing cloud.

rate) of the bottleneck link, the round-trip delay time (RTT) and the smoothed RTT (SRTT).

- **Device setup.** The IoT measuring device is initially set up from a personal computer. Configuration parameters may be then overwritten using a simple local interface (display, buttons - see Fig. 3) or using a remote connection (through a text terminal).
- **Manual measurements.** Measurements may be carried out in manual mode, triggered by the user.
- **Automatic measurements.** Measurements are triggered by predefined timers set.
- **Local monitoring of transmission path state.** Intended for use at the deployment stage of the IoT system, which facilitates the checking of the fulfillment of design assumptions and the finding of damages, unexpected errors, and misconfigurations. Local monitoring is also useful in failure diagnostics.
- **Remote monitoring of transmission path state.** Useful for all stages of the life cycle of IoT networks, especially during the exploitation stage. Critical results of the continuous estimation of path states may result in the reconfiguration of IoT devices, the automatic reconfiguration of network topology, and even force the reconstruction of the IoT network.
- **Distributed measurements.** Remote monitoring facilitates distributed measurements, which may be carried out simultaneously in different points of attachment to the tested network. Results of these measurements are collected in measuring servers that monitor the state of the tested network.
- **Dashboard.** The dashboard allows a network administrator to control distributed measurements through a measuring server, and enables visualization of path states. Analytic data about the network state, that can be used for the processing of network planning, or designing of IoT devices and services, also are available via dashboard.
- **Short- and long-term logging.** Short-term logging is carried out directly in IoT measurers. Long-term logging is performed both in data bases in servers (operational data) and archived in data warehouses.

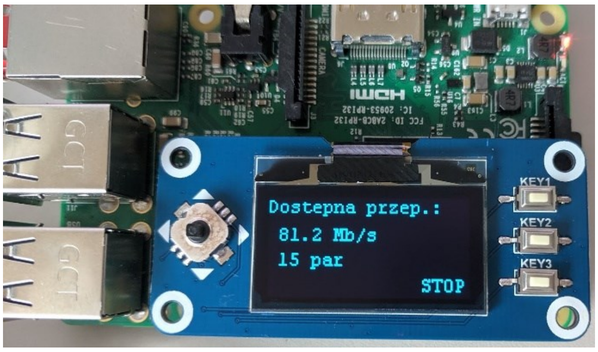

Fig. 3. Path state measurer during local, manual measurement. Available throughput ("Dostępna przepustowość]" in Polish) is 81.2 Mbps, packet train was set to 15 pairs. The right, down button stops measurements.

III. Conclusions

Presented tool allows users for estimation of state of transmission paths. As a measurement method, the packet pairs family of algorithms was used, which consists in sending of pairs of packets and observation of time parameters of pairs echoed by the other end system. This method is low invasive. It injects to networks relatively small number of packets. Therefore, it is suitable for constant monitoring of IoT networks and (if more than one device is used) for monitoring carried out from many endpoints. In contrast to similar tools, we send packets in uninterruptable bursts, using our authors method of atomic network operations. Future works will be focused on improvement of measurements accuracy and on the use of performed measurements to manage IoT systems.

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