Demo Abstract: How Temperature Affects IoT Communication

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***Abstract*—In the future we will rely on applications built on top of the Internet of Things (IoT). Example applications are smart cities, smart grids and smart healthcare. These IoT applications require a reliable service with predictable quality, and that sensor data and actuator commands are delivered reliably and timely. Unfortunately, IoT performance is highly affected by environmental conditions, especially by ambient temperature. It is therefore necessary to configure an IoT system such that sufficient application performance is provided under all environmental conditions that may be encountered.**

In this demonstration, we show how ambient temperature affects the performance of an IoT application. Specifically, we connect remotely to a large-scale temperature-controlled testbed and show how temperature affects the operation of a state-of-the-art routing protocol. Using a local setup, we further demonstrate how the impact of temperature on communication links can be easily captured and modelled in order to inform the design of communication protocols robust to high temperature fluctuations.

I. Introduction and Motivation

The Internet of Things (IoT) will enable applications of utmost societal value including smart cities, smart grids and smart healthcare. For the majority of such applications, strict dependability requirements are placed on IoT performance, and sensor data as well as actuator commands must be delivered reliably and timely. Whilst existing IoT solutions are designed to provide such dependable performance, many typically fail, as embedded wireless systems are significantly affected by their often hostile environment. Radio interference from other wireless equipment and electrical appliances impairs communication, whilst temperature and humidity variations affect battery capacity and electronics.

Recent research has revealed that operations of wireless sensor systems are largely affected by their on-board temperature. Temperature variations can significantly affect the quality of wireless links [1], battery capacity and discharge [2], as well as clock drift [3]. Deployed wireless sensor systems can undergo substantial variation in temperature depending on the enclosure and on the deployed location. Systems exposed to sunshine can easily experience high temperatures up to 70 degrees Celsius – especially if the packaging absorbs infra-red (IR) radiation [4]. High temperature may also be accompanied by high variation as seen in [5], which showed that the on-board temperature of a system can vary in an outdoor deployment by as much as 35°C in one hour and 56°C over the course of a day. In previous work, we showed that this extreme variance can reduce the received signal strength (RSS) between communicating nodes by more than 6 dB [5], which is enough to change the packet reception rate (PRR) of what was a good link from 100% to 0%.

Whilst RSS fluctuations on a link caused by temperature changes have been well studied [1], [5], the effect of these changes on networking protocols have received little attention. A deep analysis of how such effects on individual links affect the operation of networking protocols is necessary to inform the design of more dependable systems. In this demonstration we present an initial investigation into how variations in temperature affect the received signal strength and the behaviour of state-of-the-art IoT routing protocols. We also demonstrate how temperature effects on RSS can be captured and modelled in order to inform the design of robust networking protocols able to mitigate the effects of temperature variations.

II. Demo Description

Our demo is made up of two parts. In the first part, we will connect to TempLab [6], a temperature-controlled experimental infrastructure with the ability of precisely varying the on-board temperature of wireless sensor nodes, to demonstrate how temperature affects IoT communications. We put specific emphasis on the operation of a state-of-the-art routing protocol. In the second part, we will demonstrate how such temperature effects on communications can be quantified by measuring the signal degradation using a local demonstration made of four Maxfor MTM-CM5000MSP wireless sensor nodes of which two will be heated using infra-red heating lamps.

Remote testbed at TU Graz. For the first part of the demo, we will connect to a live experiment running on our experimental infrastructure at TU Graz. The testbed will be configured to replay pre-recorded individual outdoor temperature traces on 17 Maxfor MTM-CM5000MSP wireless sensor nodes. The nodes will be running Contiki's IPv6 Routing Protocol for Low-Power and Lossy Networks (ContikiRPL) [7] with each node periodically sending packets to the sink. We will illustrate the impact that temperature variations have on key network metrics such as throughput, delay and lifetime, showing that it is fundamental that temperature effects are taken into account when designing robust networking protocols. Along with the sensor nodes and controllable infra-red lamps, the testbed facility in Graz offers the possibility to observe an experiment using a steerable Web-cam (Figure 1). This facility will be used during the demo to monitor the live experiment.

Measuring temperature effects on communication. Along-side the observation of the remote demo, we will use a small-scale version of our testbed infrastructure at the EWSN

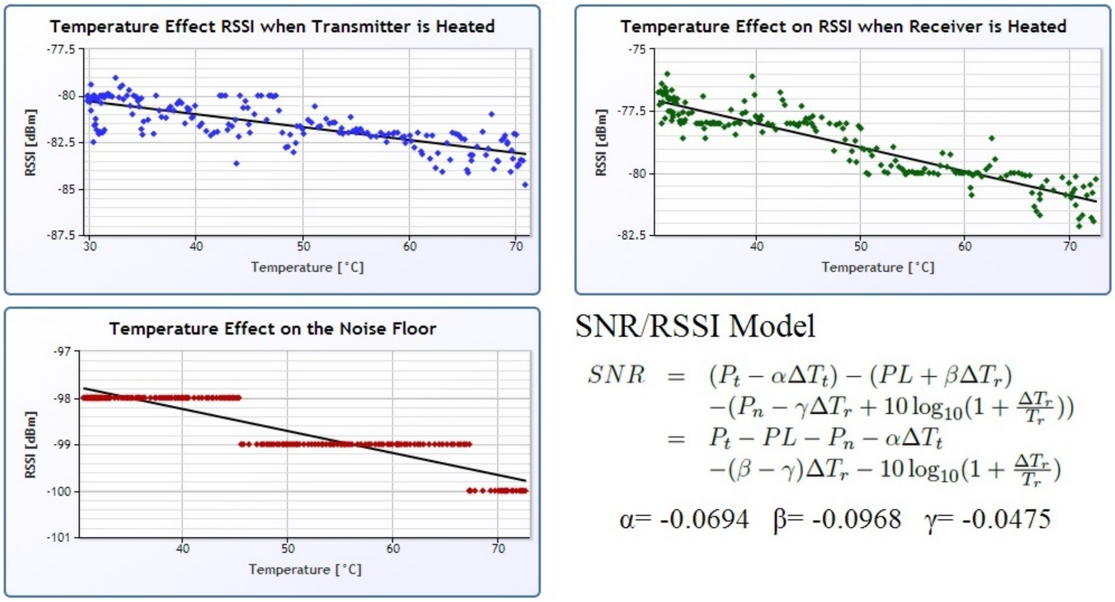

Fig. 2. Real-time capture of the degradation of the wireless link quality as a function of temperature, and parametrization of a first-order model.

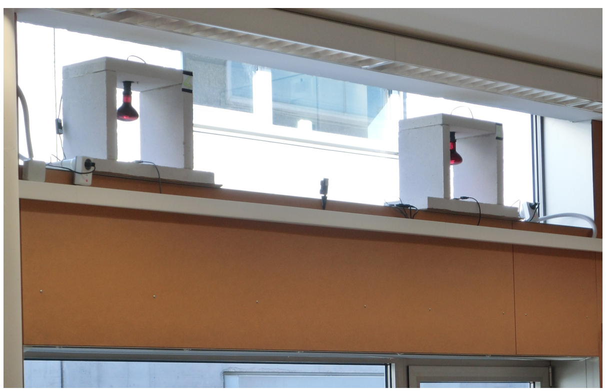

Fig. 1. Snapshot of the testbed infrastructure available at TU Graz taken remotely using the steerable Web-cam.

demo session to capture how link quality degrades at high temperatures. Specifically, we will use four Maxfor MTM-CM5000MSP wireless sensor nodes of which two will be heated using infra-red heating lamps similar to the ones shown in Figure 1. The demo will show how the dependency between temperature and link quality can be determined in real-time by measuring temperature and signal strength information.

In particular, we form two independent links by dividing the sensor nodes into pairs. Each link operates on individual channels to avoid effects caused by interference. Sensor nodes will run the same Contiki software periodically sending packets using a predefined transmission power to their intended receiver with temperature information measured using the on-board SHT11 digital sensor. On the receiver, statistics about the received packets[1] are logged using the serial port and collected by an application that computes the decrease in RSS as a function of temperature, as we proposed in [5]. An intuitive web-application will visualise this data as shown in Figure 2.

[1]We collect hardware-based link quality metrics in IEEE 802.15.4 compliant radio transceivers, namely the received signal strength indicator upon packet reception (RSSI) and in absence of packet transmissions (noise floor).

III. Conclusions

Variations in environmental properties can significantly affect the operations of wireless embedded systems, which can break IoT applications. In this demonstration, we have shown that temperature variations can drastically affect the performance of communication protocols, with particular focus on the state-of-the-art ContikiRPL. We have further demonstrated how the temperature effects on received signal strength can be captured to parametrize a first-order model that can be used in future protocols to predict changes in link quality and minimize the impact of temperature fluctuations.

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