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Utilizing Cost-effective NB-IoT-based Sensors for Detecting Water Temperature and Flow

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Research Context

- **Prototype development**
- Software orientation
- Utilization of **off-the-shelf devices**
  - smartphones and tablets
  - Arduino, Raspberry Pi, etc. Single Board Computers(SBC).
  - Sensors (heat, humidity, pressure, movement, position, etc.)
- Communication technologies (Ethernet, WiFi, ZigBEE, LoRa, NB-IoT, etc.)
- Cloud-based services and data analysis
- Growdsourcing based data

Our paper – Water temperature and flow

- Motivation
  - Improperly turned off sink and shower faucets, leaking toilets, and faults in pipes can cause expenses and serious problems
  - Commercial water leak detectors are mostly installed in the main water meters
    - Can detect overall leaks, and cannot pinpoint the location of the leak
  - Leaking can be detected by measuring temperature changes of water
- Purpose:
  - To use cost-effective off-the-shelf devices to build data gathering prototype.
  - Devices are selected with low power features
  - To develop open and modular **proof-of-concept monitoring system**
- Goal:
  - Flow detection –prototype system
  - Gather and analyze data from water flow
  - Feasibility study, method rapid prototyping

Assumptions and limitations

- Water systems in buildings consist of hot and cold water pipes
- When water flows, the temperature of the external surface of the pipe is close to the temperature of the water flowing inside the pipe
- When flow stops, the temperature of the pipe
  - rise in cold water pipes
  - drop in hot water pipes
- And pipes will eventually reach the ambient temperature
- By collecting temperature data from pipes, and ambient temperature, it is possible to estimate whether water is flowing or not.

Goal

- Measure water temperature from surface of the water pipe

Demands for Data gathering prototype

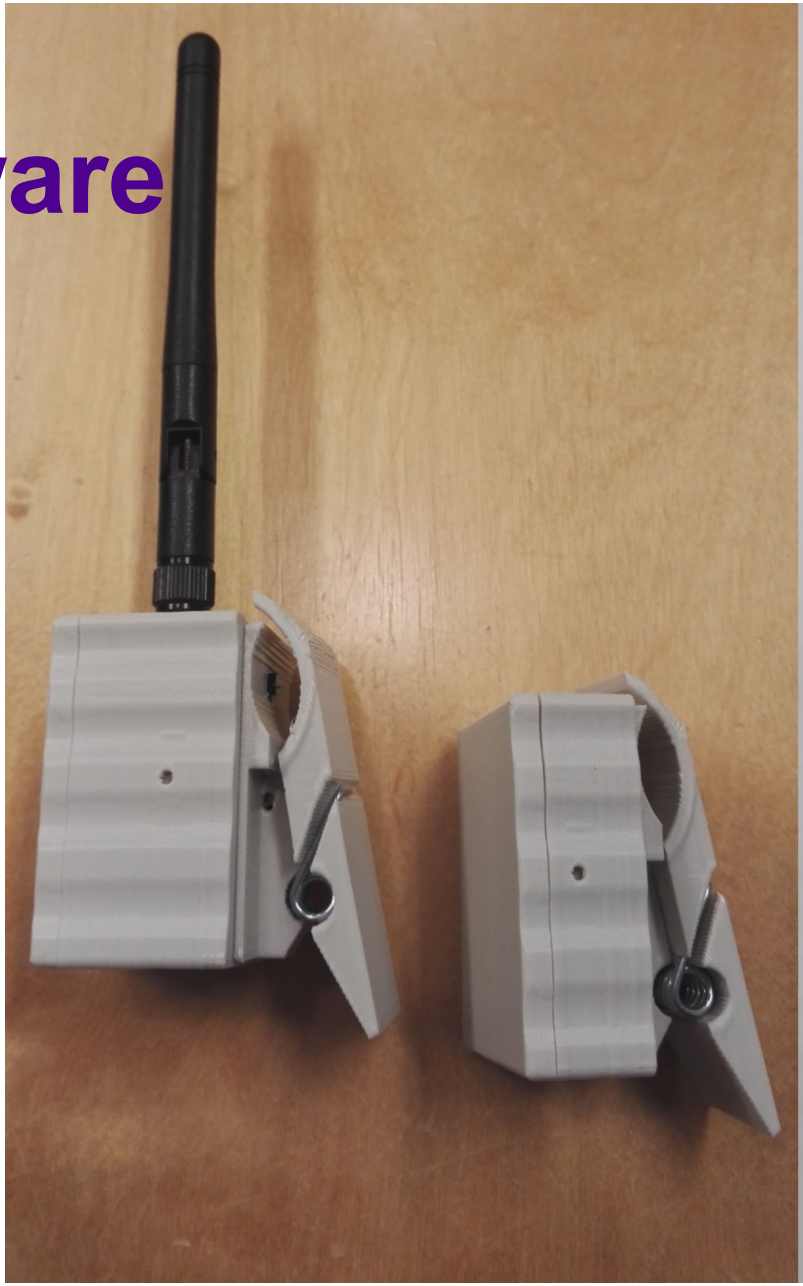
- Purpose: Gather sensor and upload the data to a cloud service
- Previous research: we have used Raspberry Pi and Arduino for similar measurements
- Previous: further develop working prototype that used the Microchip AVR ATtiny.

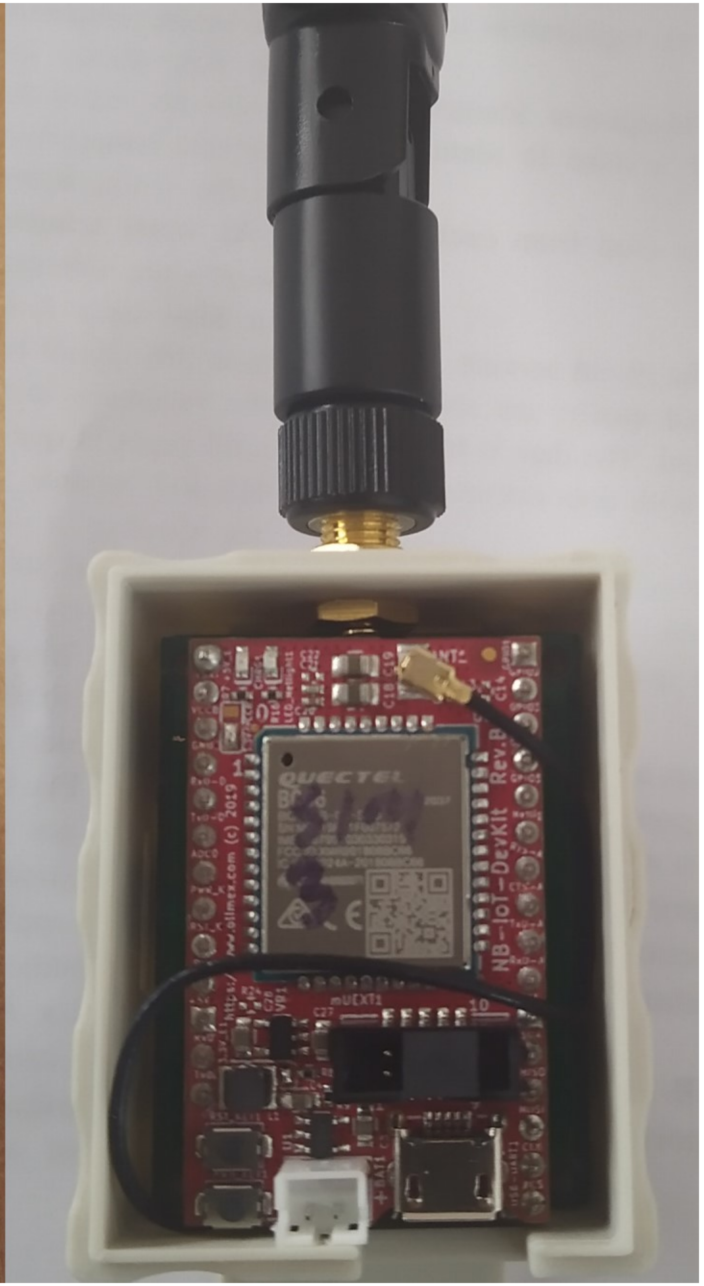
Solution

- Suitable NB-IoT modem with SBC functionality (Quectel LTE BC-66 figure ->)
  - Wireless communication
  - smaller device size
  - (Theoretically) lower power consumption for battery power
- Separate temperature sensors

Prototype - hardware

- NB-IoT development board with Quectel LTE BC-66 module and programmer
- Includes e.g., GPIO, I2C, SPI, UART, USB power
- 3D printed case
- Three separate DS18B20 temperature sensors





Prototype - software

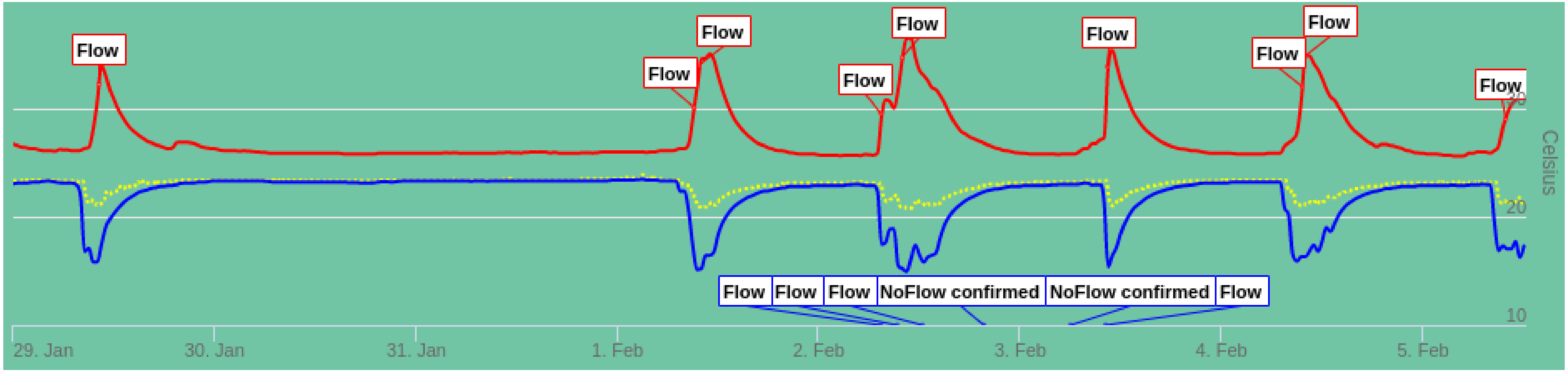
Software executed directly on the NB-IoT module and programmed using the OpenCPU SDK created by Quectel

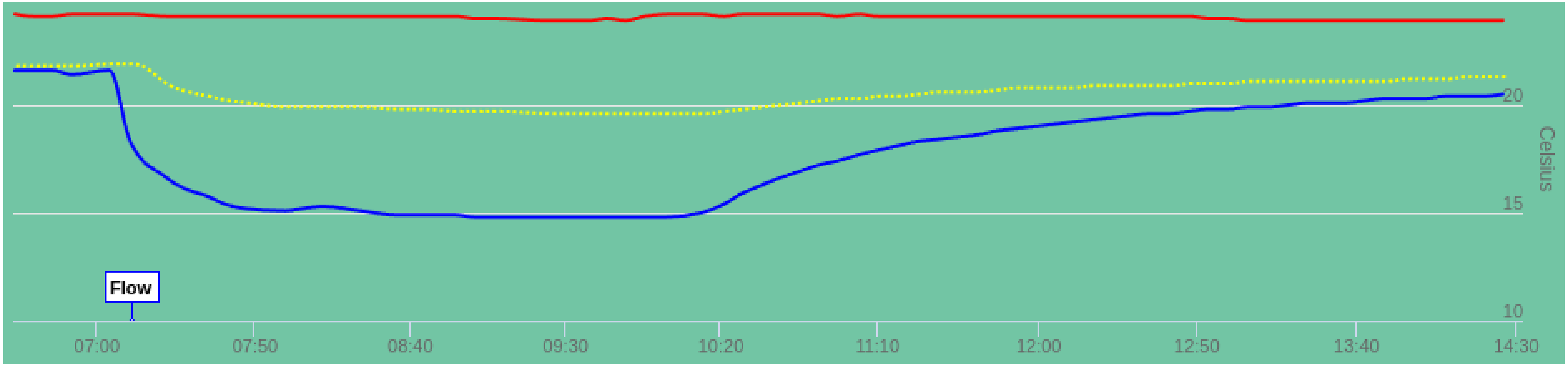
1. The device wakes up from deep sleep
2. NB-IoT network registering.
3. The IMEI (International Mobile Equipment Identity) and signal quality are read. IMEI is used to identify the devices in the cloud service.
4. Read temperature measurements from three sensors.
5. Read the voltage.
6. Opening TCP/IP socket to the cloud service. Data are sent to the service.
7. The RTC timer is set up to wake up the device after interval.
8. Entering deep sleep state to conserve power.

Testing the prototype

- Four prototypes installed in the campus of Satakunta University of Applied Sciences(located in Rauma, Finland).
- Testing began in March and still going on.
- Results show normal usage in public areas of campus in daytime.
- No leaks detected

Data from the cloud server





Findings 1/2

- Detect water leaks of about two liters per hour (minimum)
  - tested with polyethylene (PEX-Ax, EN ISO 15875) and (20 mm and 35 mm) and copper pipes.
- The detection accuracy could be improved by using more accurate temperature sensors,
- During night the time leak detection is easier - because no significant water usage outside operating hours.
- Detection algorithm based on pre-configured temperatures - found by experimentation.
- Does not show the amount of leakage .
- The precise water flow (l/h) could be detected in theory by measuring the variances in the three temperatures (ambient, hot pipe, cold pipe)
- Sensors could track the minimum or maximum temperatures to prevent unwanted bacterial growth in drinking water.
- In northern Europe the pipe insulations make possible to use the algorithm
  - But if the pipe insulations missing (southern Europe) the algorithm have to change.

Findings 2/2

- The NB-IoT module run a simple application code that gathers sensor readings and submits them to a cloud service.
- Lack of hardware documentation (e.g., error codes) and examples can make application design, implementation, debugging, and testing a challenging.
- Circuit examples should be carefully studied (e.g NB-IoT Devkit's serial data lines require additional resistor filters compared to Raspberry Pi)
- The sensor order in the 1- wire interface can vary (Oddity - it should not!)
  - - The server corrects the order of the sensors
- Physical location of sensor cause the variation in ambient temperature
- NB-IoT (4G technology) works fine.

Thank you!
Questions?