re:mote – Low-cost Software and Hardware Infrastructure for Water Quality Sensing in Indigenous Communities

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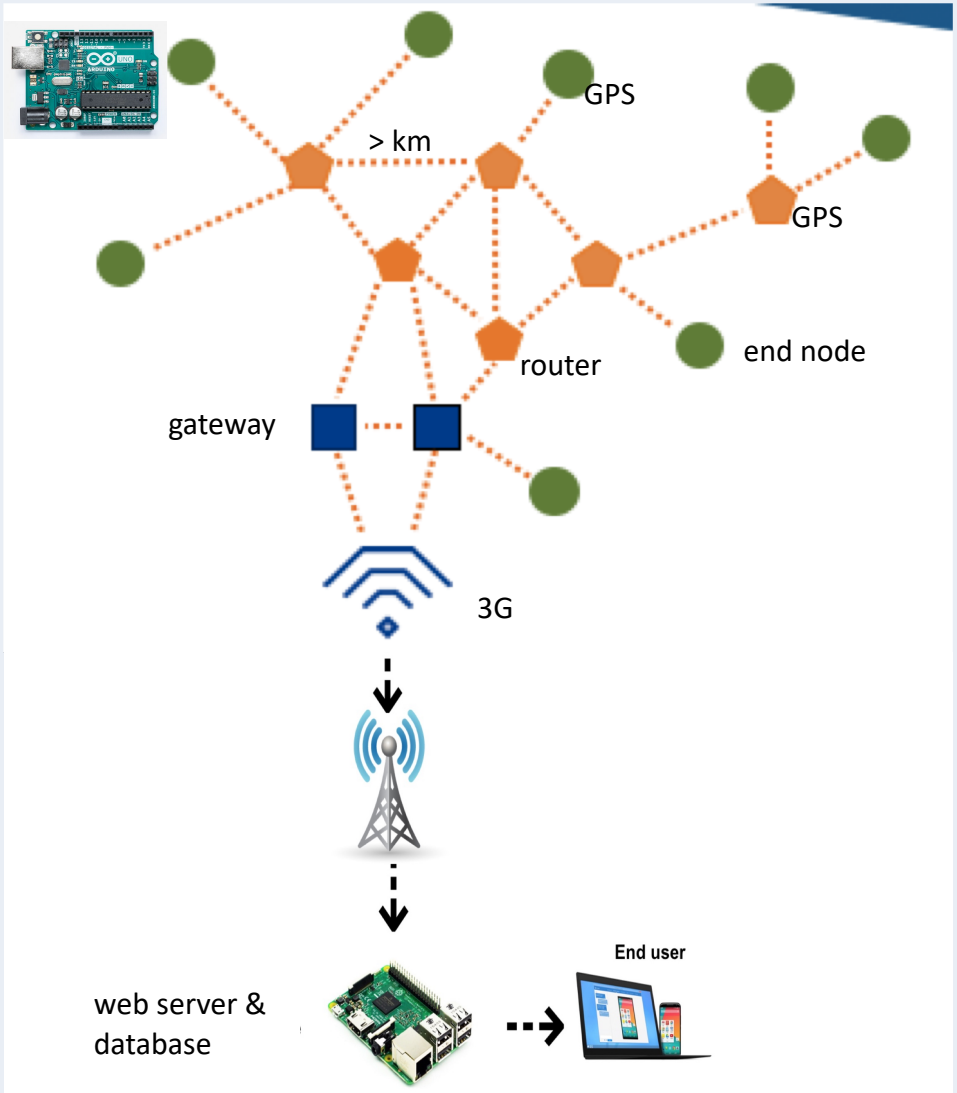
- 3G/4G connection to server
- LoRa low-bandwidth, low-power, long-range mesh network
- Tolerant to faults, changing topology



Low-Power Long-Range Mesh Sensor Network

- Sensor nodes with off-the-shelf probes for DO, pH, conductivity, turbidity, air & water temperature, humidity
- Battery & solar operated
- Data with GPS coordinates transmitted via LoRa to gateway
- Data buffered in case of network failure

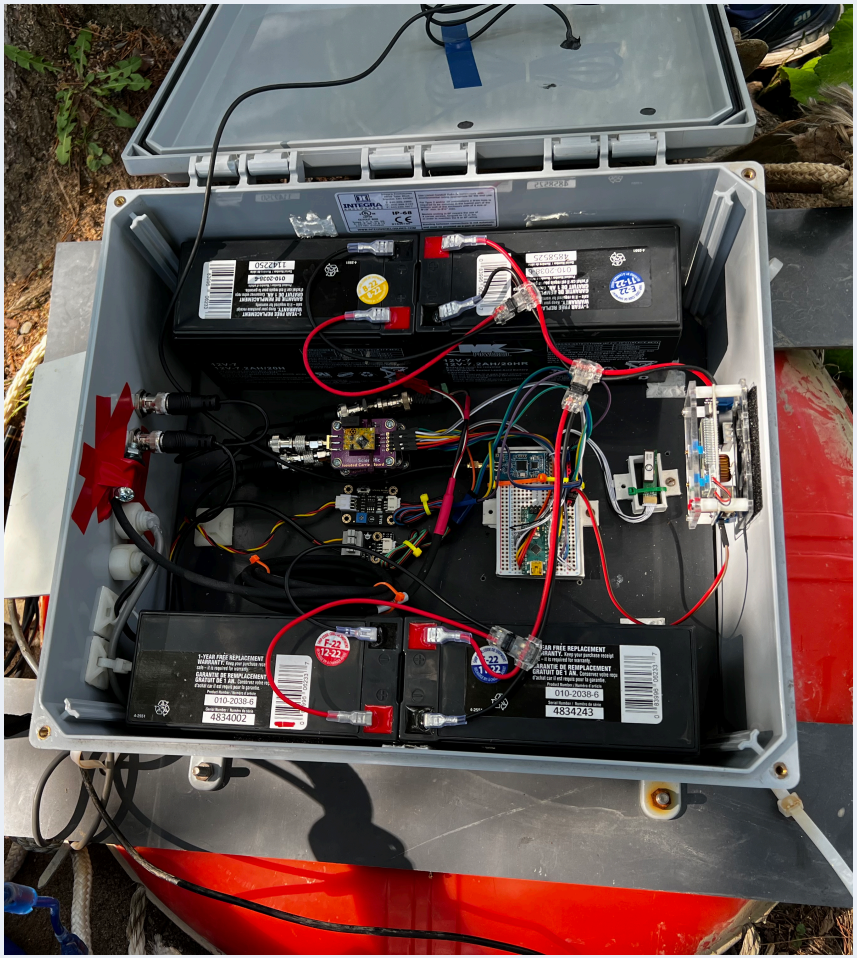
Dr Charles de Lannoy & Team deploying a sensor node at Six Nations

Mesh Network for Deployment in Remote Areas

- Gateways receiving from sensor nodes via LoRa and sending to server via 3G/4G
- Routers forwarding data in a mesh network
- Data buffered in case of network failure

Cost Sensor Node

Category	Parts	Count	Price (CAD after tax)	Cheaper solution
Main Board				
	Arduino Nano	1	62.61	4.06
	Mesh LoRa	1	19.95	19.95
	Breadboard PCB	1	7.44	1.53
Sensor				
	Conductivity Kit	1	351.07	351.07
	Dissolved Oxygen Kit	1	407.40	407.40
	Turbidity Sensor	1	12.97	12.97
	Temperature Sensor Kit	1	9.83	9.83
	Industrial pH Probe	1	307.84	307.84
	EZO™ Carrier Board for pH	1	37.98	37.98
	EZO™ pH Circuit	1	60.25	60.25
	GPS Receiver - GP-735	1	64.85	64.85
	JST connector (for GPS)	1	2.53	0.37
Power				
	SLA Batteries	4	203.35	26.56
	Battery Voltage Converter	1	33.35	9.24
Total			1581.40	1313.88



Cost Gateway / Router

Category	Parts	Count	Price (CAD after tax)	Cheaper solution
Main Board				
	Arduino Uno	1	31.63	9.03
	3G Shield	1	78.53	57.93
	Mesh LoRa	1	19.95	19.95
	MicroSD Card	1	10.17	10.17
	MicroSD Card Reader Module	1	6.51	0.46
	Ribbon Cables	1	11.85	0.78
Sensor				
	DHT Sensor	1	18.63	0.88
Power				
	SLA Batteries	2	101.68	13.28
	Battery Voltage Converter	1	33.35	9.24
	Battery Connectors	1	19.20	3.37
Enclosure				
	Waterproof Box	1	48.58	10.62
	SMA Extender	2	11.85	3.98
Connectivity				
	SIM Card with data plan (120 days)	1	38.25	38.25
Total			430.18	177.94

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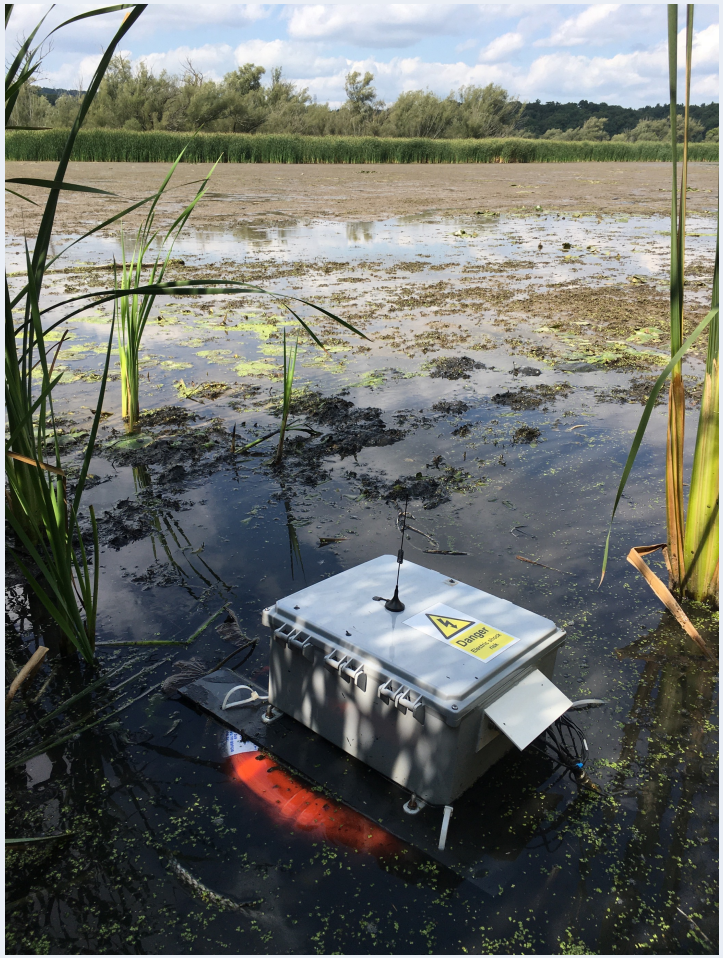
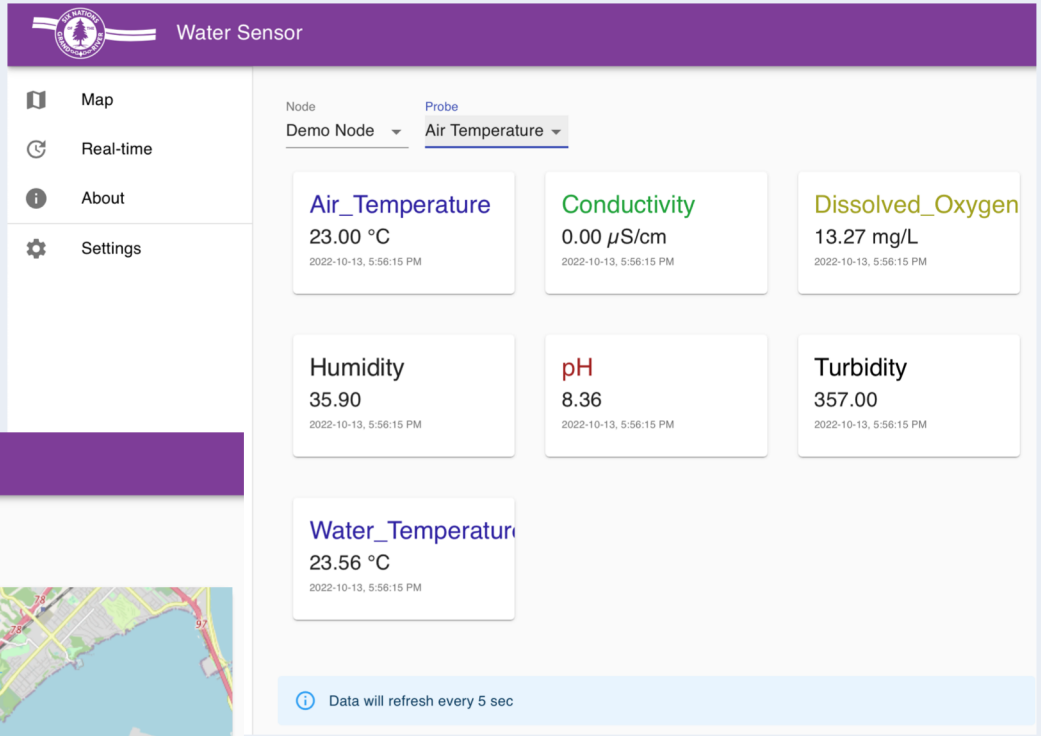
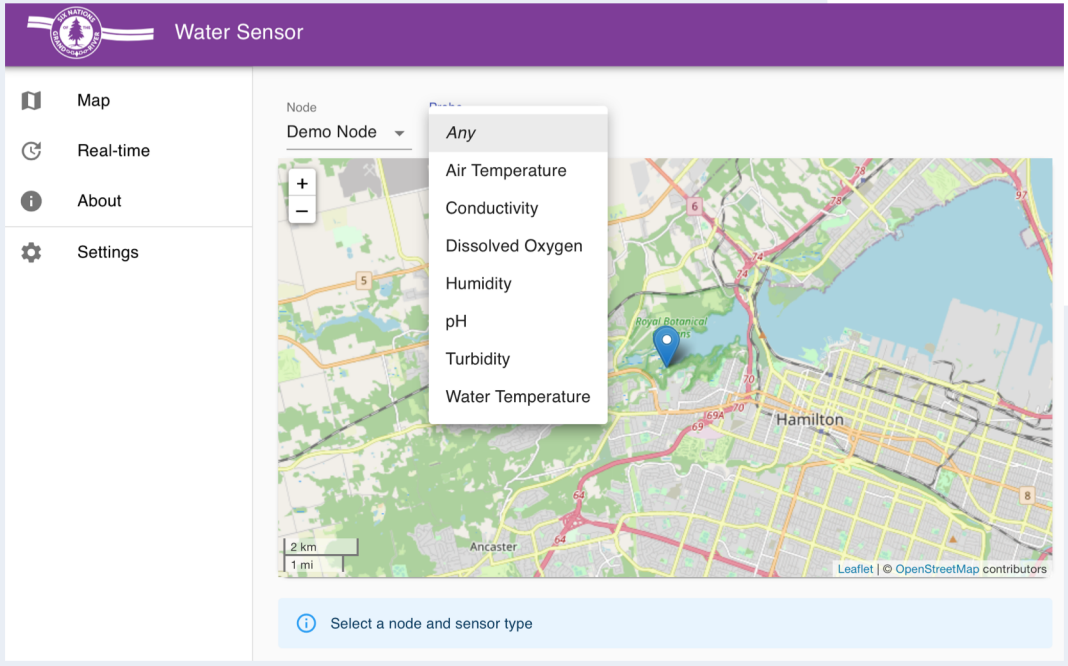
Test Deployment at Cootes Paradise



Multilingual Mobile Web Site with Real-time Data

https://macwater.cas.mcmaster.ca





Open-Sourced Hardware and Software

https://gitlab.cas.mcmaster.ca/re-mote

Server:

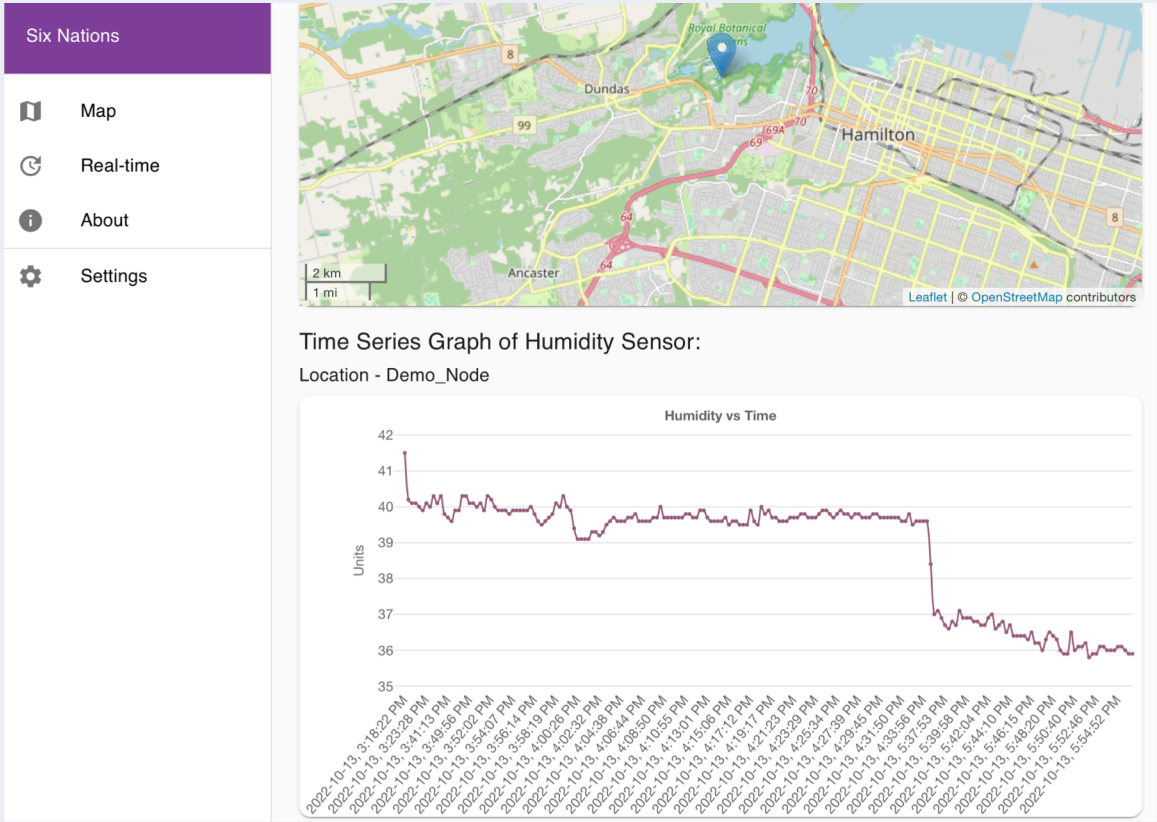
- 500 lines GO

Website:

- 1700 lines TS React

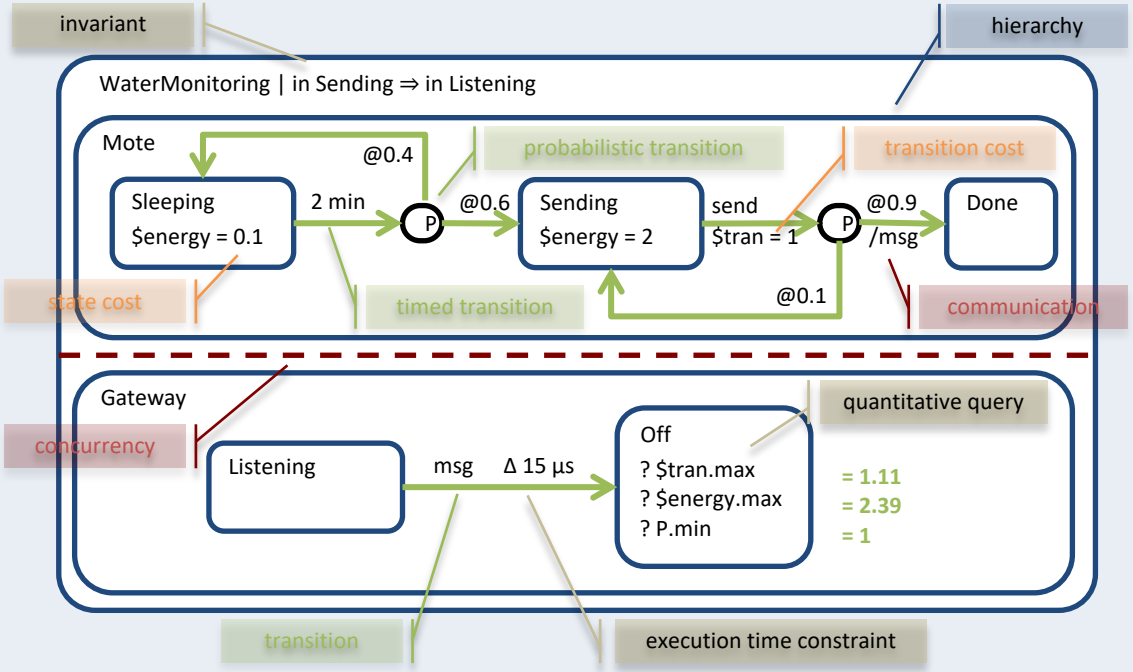
Gateway & Sensor Nodes:

- 3500 lines C++



Model-Driven Development

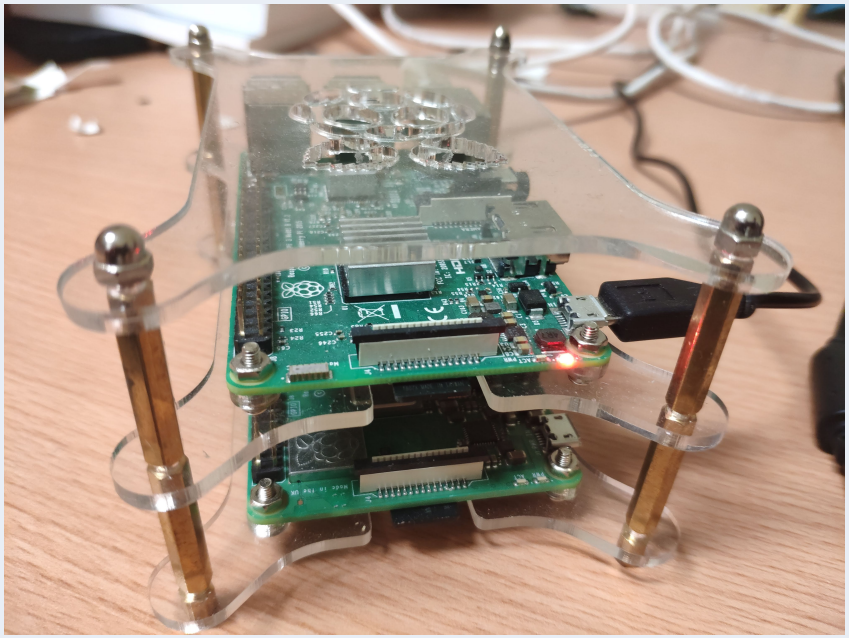
- Correctness, reliability, power consumption, execution time deduced from formal model of motes + environment
- pState: extended state diagrams in front end, probabilistic model checker and SMT (satisfiability modulo theories) solver in back end



Low-cost Server

Raspberry Pi, ≈ $100

- Programmed in Go for fast, concurrent connections
- Progressive web application designed in React with a custom API
- InfluxDB as time-series database



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Time Series Databases for Water Quality

Time Series Databases as an alternative to Relational Databases:

- simpler data model, one column is timestamp
- assume insertions are frequent compared to queries
- fast insertion of large amounts of data
- queries can be summarizing in interval, e.g. min, max, average
- retention policies to eliminate unwanted data
- smaller footprint
- used for high-frequency events, e.g. server logs, stock trades

A Comparison of Time Series Databases for Storing Water Quality Data

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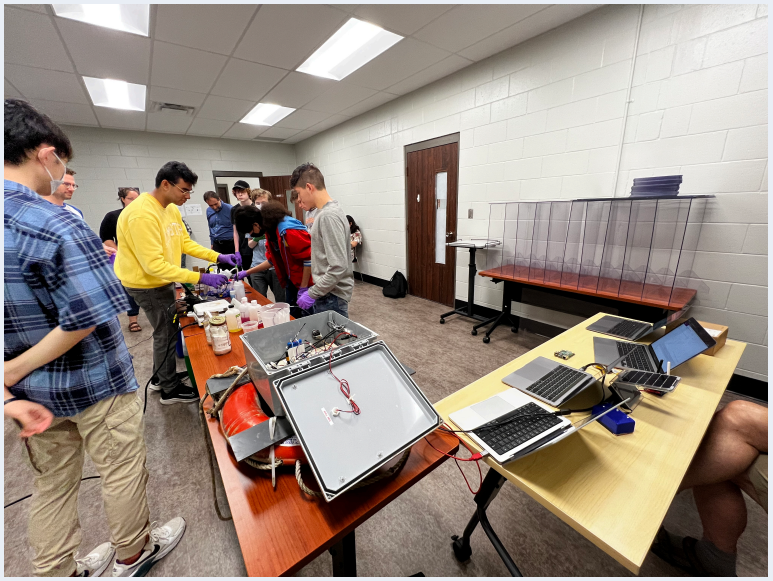
Abstract. Water quality is an ongoing concern and wireless water quality sensing promises societal benefits. Our goal is to contribute to a low-cost water quality sensing system. The particular focus of this work is the selection of a database for storing water quality data. Recently, time series databases have gained popularity. This paper formulates criteria for a comparison, measure selected databases, and makes a recommendation for a specific database. A low-cost low-power server, such as a Raspberry Pi, can handle as many as 450 sensors' data at the same time by using the InfluxDB time series database.

High School Outreach at STEAM Academy

Dr Charles de Lannoy explaining



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Select Publications

- Zhang, Qianqian, Zhong Li, Lu Zhu, Fei Zhang, Emil Sekerinski, Jing-Cheng Han, and Yang Zhou. 2021. “Real-Time Prediction of River Chloride Concentration Using Ensemble Learning.” *Environmental Pollution* 291 (December):

- Fadhel, Muntazir, Emil Sekerinski, and Shucai Yao. 2019. “A Comparison of Time Series Databases for Storing Water Quality Data.” In *Mobile Technologies and Applications for the Internet of Things, IMCL 2018*, edited by M. Auer and T. Tsiatsos, 909:302–13. Advances in Intelligent Systems and Computing. Springer.

- Wang, Xi, Emil Sekerinski, and John Copp. 2019. “Automated Detection of Anomalies in High Frequency Water Quality Sensor Data Using Machine Learning.” In *48th Annual WEAO Technical Symposium & OPCEA Exhibition*, 116. Water Environment Association of Ontario.

- Copp, John B., Prabhbir Pooni, Winfield Lai, Xi Wang, Roman Viveros, and Emil Sekerinski. 2019. “When Grab Samples Just Won’t Do: High-Quality High-Frequency Water Quality Monitoring.” In *48th Annual WEAO Technical Symposium & OPCEA Exhibition*, 1–4. Water Environment Association of Ontario.

- Park, Spencer, and Emil Sekerinski. 2018. “A Notebook Format for the Holistic Design of Embedded Systems (Tool Paper).” In *Proceedings 4th Workshop on Formal Integrated Development Environment, Oxford, England, 14 July 2018*, edited by Paolo Masci, Rosemary Monahan, and Virgile Prevosto, 284:85–94. Electronic Proceedings in Theoretical Computer Science. Open Publishing Association.

- Nokovic, Bojan, and Emil Sekerinski. 2016. “Automatic Quantitative Analysis and Code Generator for Sensor Systems: The Example of Great Lakes Water Quality Monitoring.” In *Internet of Things. IoT Infrastructures: Second International Summit, IoT 360º 2015*, edited by Benny Mandler, Johann Marquez-Barja, Miguel Elias Mitre Campista, Dagmar Cagáňová, Hakima Chaouchi, Sherali Zeadally, Mohamad Badra, et al., 170:313–19. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering. Springer.

- Nokovic, Bojan, and Emil Sekerinski. 2015. “A Holistic Approach in Embedded System Development.” In *Proceedings Second International Workshop on Formal Integrated Development Environment*, edited by Catherine Dubois, Paolo Masci, and Dominique Méry, 187:72–85. Electronic Proceedings in Theoretical Computer Science. Open Publishing Association.

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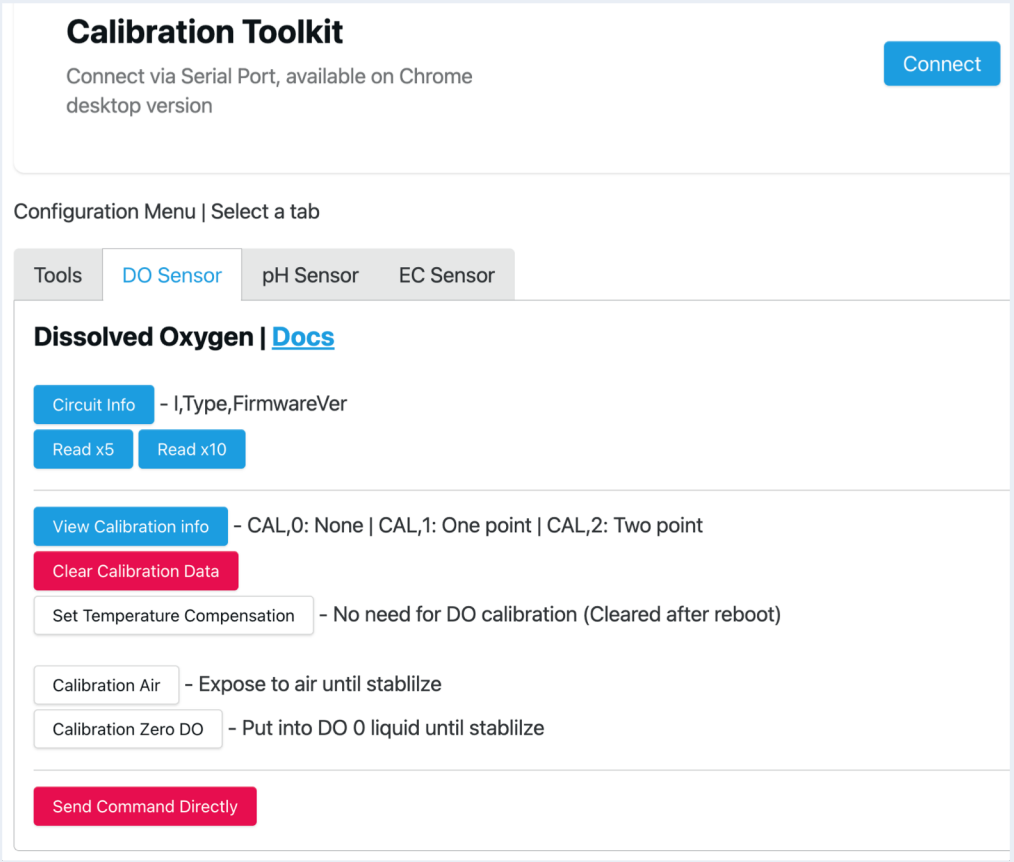
Ongoing Work

- Instructional visualization of data
- Auto-configuration of sensor nodes, gateways, routers
- Secure transmission of data
- Authorization with different levels of privilege
- Improved mesh networking
- Extending battery life



Why LoRa?

LoRA:

- mesh network, low power, slow, long range, penetrates obstructions

3G/4G:

- star network, high power, fast, long range, blocked by obstructions