

Request for Research Funding for FY 2023-2024

Project Number (Research Center Use Only): TEO-24-10

Requesting Office	District 5 Traffic Operations	Priority High	10 of 11
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Proposed Title Exploring Hybrid Architecture for Data Processing/Storage Needs of FDOT

Justification

The Florida Department of Transportation (FDOT) uses huge streams of data transmitted by smart roadways covering more than 12000 miles and over 3000 transportation sensors to monitor and manage traffic across Florida. The data gets archived at Central Data Warehouse (CDW), monitored/analyzed by the Regional Integrated Transportation Information System (RITIS), and is used to manage and control traffic via SunGuide by many Traffic Management Centers (TMCs) through SunGuide's built-in data exchange and interoperability features (FDOT, 2022).

Many natural catastrophes cause large-scale infrastructural damage, triggering power outages and network failures across entire cities, spanning multiple days. Recently, during (Hurricane Ian, 2022), out of 14 thousand cellular towers in Ian's path, 1152 reported out-of-service; that is close to 11% failure that peaked at 65% in hard-hit areas of Ft. Myers (Hurricane Ian - Federal Communication Commission, 2022). In a survey by a newspaper group, The Sun, more than 90% of Charlotte's traffic signals were damaged (YourSun, 2022).

Cloud-based data storage and processing is one potential solution that FDOT is currently exploring to provide more robustness and resilience for its operations. However, sending unprocessed bulk data directly to the cloud servers introduces a potential central point of failure: communication reliability between the sensors and the cloud servers. Moreover, processing raw data on cloud servers leads to high latency, which can be hazardous for specific safety-critical applications. A part-edge-part-cloud solution holds the potential to remove strict dependence on the cloud servers and reduce the total latency. However, it is challenging to design a hybrid model that balances the data and compute burden such that the system remains feasible in terms of cost, reliability, and security. Therefore, it is necessary to carefully design a research pipeline that involves rigorous design, experimentation, and evaluation cycles to iteratively build the solution.

This proposal proposes a three-stage plan to augment FDOT's efforts in exploring the hybrid cloud approach for data storage and computational needs. In the first stage, I) a sample sensor node, that is, the complete kit containing all the parts (sensor, interface box, cables, etc.) that FDOT deploys, is acquired by the research team at UCF and is connected to a virtualized machine running at FDOT's servers. The virtual machine act as a simulated cloud server running a copy of selected applications (to be decided in consultation with FDOT) that processes the data from the sensor node. The machine is a virtualized environment and is usually considered safe, but for added safety, the connection is recommended to be secured by a Virtual Private Network (VPN) via Secure Socket Tunneling Protocol (SSTP). In the second stage, II), the application solution running on the virtualized machine, which completely relies on the cloud server for computation, is investigated, and a hybrid solution is designed, considering cost, reliability, and security as the metric. Here, a suitable compute unit is searched and added to the sensor node, followed by the development of a summarization/compression/encoding model that efficiently pre-processes sensor data and generates compact high-level information to be sent to the application running at the simulated cloud server. In the third stage, III), the implemented hybrid solution is evaluated based on the metrics defined earlier. The evaluations are made on simulated use cases, conditions, and environments. The research iteratively performs stage II and stage III until a feasible solution is found; reports are provided after each iteration.

Impact The project will provide 1) a short evaluation report of the currently deployed solution, 2) the part-edge-part-cloud solution that has no central point of failure and improves latency, and 3) a feasibility report considering cost, reliability, and security as a metric.

Affected Offices Traffic Engineering and Operations, Safety, Transportation Technology, and all Districts

Existing Work 1. Nguyen, N. T., Liu, B. H., Chu, S. I., & Weng, H. Z. (2018). Challenges, designs, and performances of a distributed algorithm for minimum-latency of data-aggregation in multi-channel WSNs. IEEE

	<p>Transactions on Network and Service Management, 16(1), 192-205. https://ieeexplore.ieee.org/abstract/document/8556039</p> <p>2. Singh, Sachchidanand. "Optimize cloud computations using edge computing." 2017 International Conference on Big Data, IoT and Data Science (BIGDATA). IEEE, 2017. https://ieeexplore.ieee.org/abstract/document/8336572</p> <p>3. Althoubi, A., Alshahrani, R., & Peyravi, H. (2021). Delay analysis in IoT sensor networks. Sensors, 21(11), 3876. https://www.mdpi.com/1424-8220/21/11/3876</p> <p>Wang, Tian, et al. "Edge-based auditing method for data security in resource-constrained internet of things." Journal of Systems Architecture 114 (2021): 101971. https://www.sciencedirect.com/science/article/pii/S1383762120302186 As a minimum, the Transportation Research International Documentation (TRID) and the Research in Progress (RIP) online databases should be reviewed by an expert in the research subject matter to assure research effort and resources shall not duplicate prior or ongoing work. TRID: https://trid.trb.org/Results RIP: https://rip.trb.org/</p>		
Keywords Used In Existing Work Search (Cannot leave blank)	<p>PreProcessing at Edge + Cloud Computing (Google Scholar)</p> <p>Delay Analysis in Networks (Google Scholar)</p> <p>Privacy Analysis in Networks (Google Scholar)</p>		
Related Contracts (Give contract numbers)	None.		
Funding Request	\$175K	Anticipated Duration	24 months
Project Manager	Mr. Jeremy Dilmore Co-PM: Christine Shafik, PE	Contracting Method	Direct contract with the University of Central Florida Dr Shaurya Agarwal
Equipment	None	Comments* (understanding leases are preferred, include the proposed use of the equipment, whether lease options are feasible, whether work to be done with equipment could instead be procured through service expenditure, etc.)	
Urgency	1	The project should get the highest priority as the deployment of any network-based services from FDOT are highly affected by latency and central point of failure issues.	
Implementability	1	The project has the greatest likelihood of implementing the results as it involves the use of actual equipment, networking, and processing methods as per the guidelines provided by FDOT.	
Project Benefits			
The Department is actively looking at how to handle both operational needs and the benefits of cloud computing. A hybrid solution appears to be the future direction of TSMO, but this has not been put into practice yet by vendors. FDOT has setup NG-SELS to support this approach. R-ICMS supports the approach. SunGuide has been deployed in the Northeast as Compass as entirely cloud hosted, but a myriad of risks to the continuity of operations not to mention migration costs call into question how to move forward. This project would provide insight into a potential route and provide lessons learned for our next steps.			
Project Benefits (Select all that apply and explain)	Quantifiable Benefits (units, dollars, etc...if applicable)	Methodology or Data Sources Used to Determine Quantifiable Benefits. If not applicable, please give justification of project benefits	
<input type="radio"/> Materials Enhancement			

○ Materials Savings		The project will deliver a cost-effective solution by carefully selecting the parts that are added to deliver the required improvements.
○ Time Savings		The project will deliver a reliable solution measured by a) latency and b) up-time. Latency is the time a packet takes from sending node to receiving node in a network and up-time is the time during which the application remains operational. Reduce IT Staffing needs and time spent investigating systems
○ Lives Saved/Injuries Prevented		
○ Other (Security)		The project will provide a secure solution. The data sent and received will follow practiced security standards.

*Comments should explain and support urgency, financial benefit, and implementability scores