JUNO2: Collaborative Research: STEAM: Secure and Trustworthy Framework for Integrated Energy and Mobility in Smart Connected Communities (US-Japan Collaboration)

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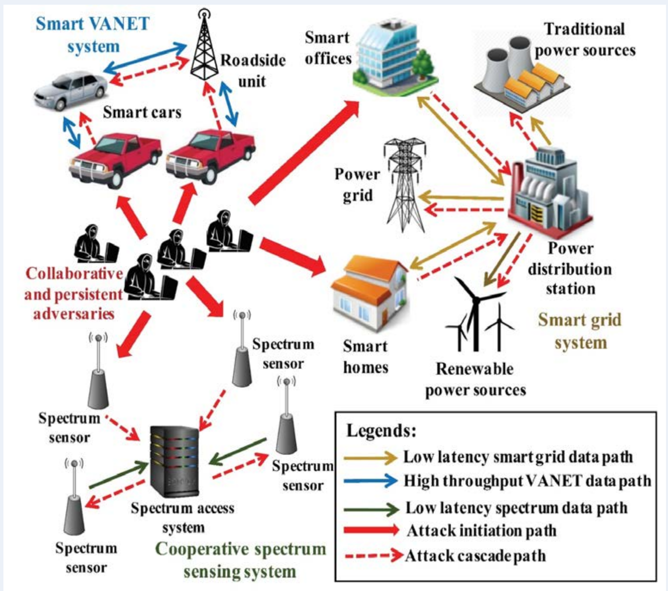
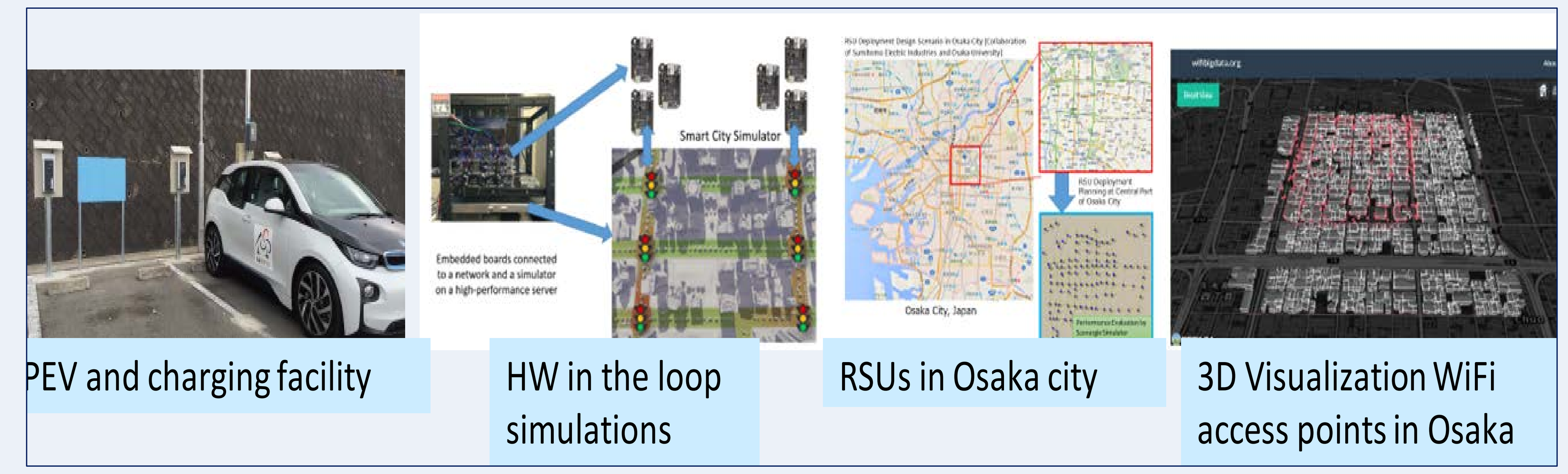
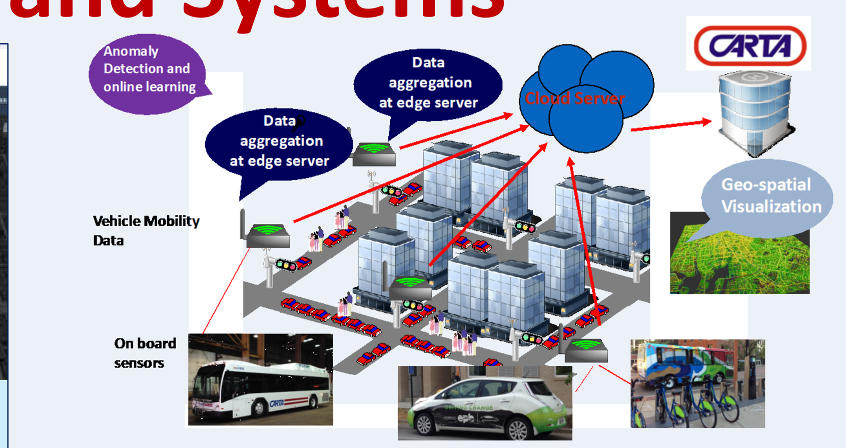


STEAM Project: Objective

- Develop integrated frameworks, algorithms and models to address security and trustworthiness challenges in mobility and energy under various threats.
- Design lightweight resilient anomaly detection and privacy preserving encryption schemes; a middleware architecture.
- Mechanisms to handle conflicting goals of identifying anomalies; preserving privacy and integrity at scale.
- Efficient co-design and calibration of encryption and robust anomaly detection schemes.

Validation with Real Datasets and Systems





Transit Operations in Chattanooga and Nashville

Efficient Anomaly Detection

Threat Model: Orchestrated attacks on a collection of sensors to maximize the effect of attack on the global transportation system

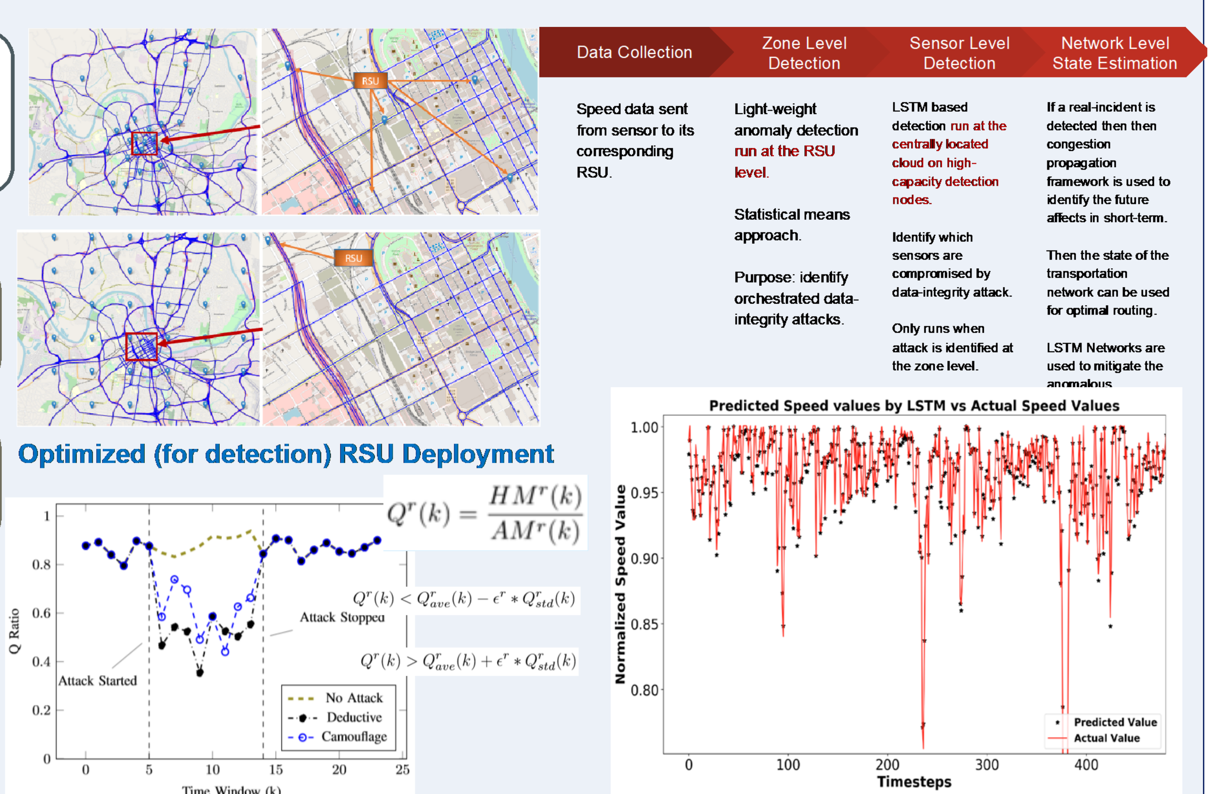
Tried on real data from Nashville, TN

Optimal RSU Placement: designed for optimal anomaly detection using ROC curves

Macro Model: designed for large scale decentralized anomaly detection in real time

Micro Model: highly accurate and fine grained-anomaly detection. Computationally intensive

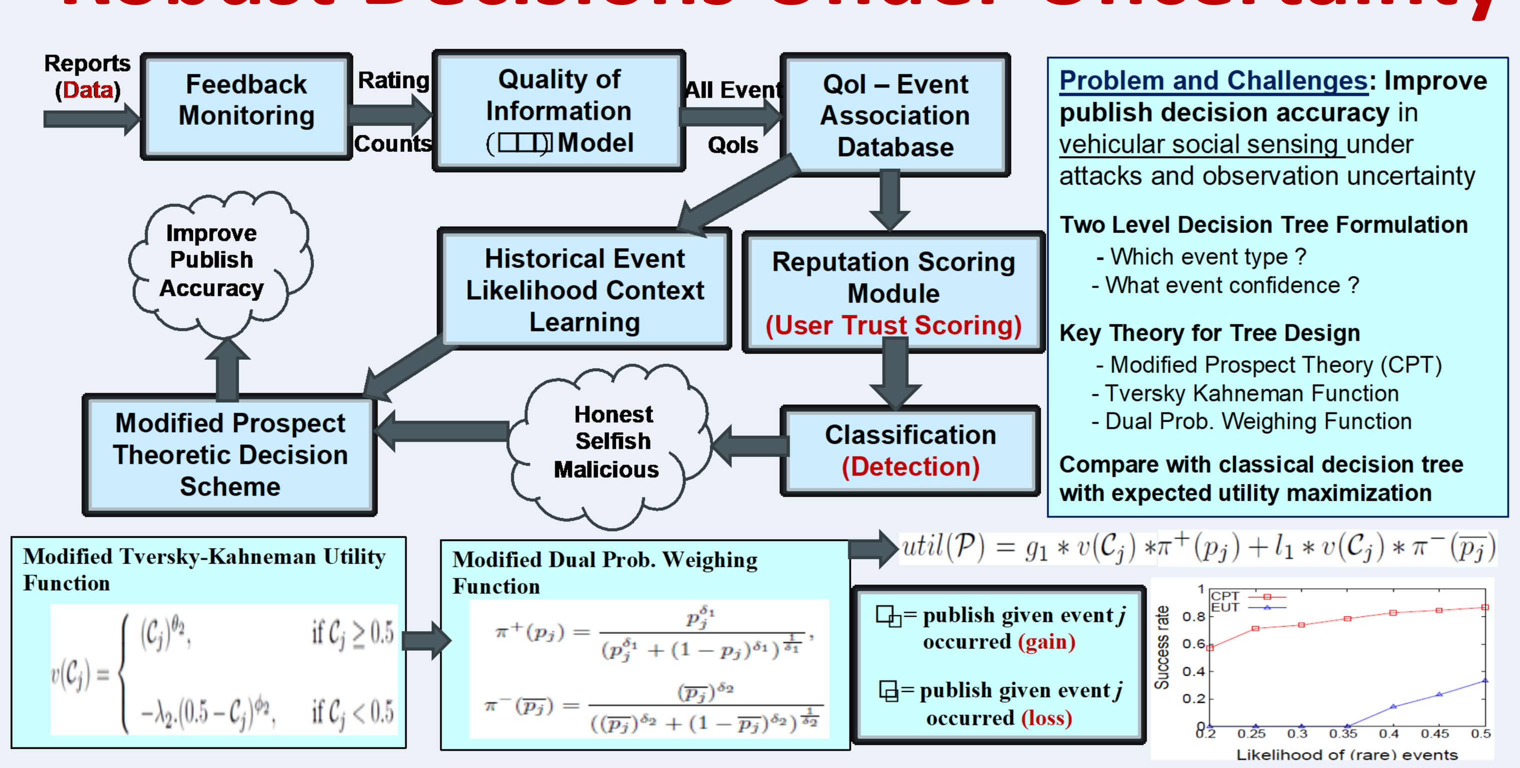
Congestion Progression: how the effects of anomalies propagate through the network



Macro-Level Detection: Built efficient streaming statistical algorithm

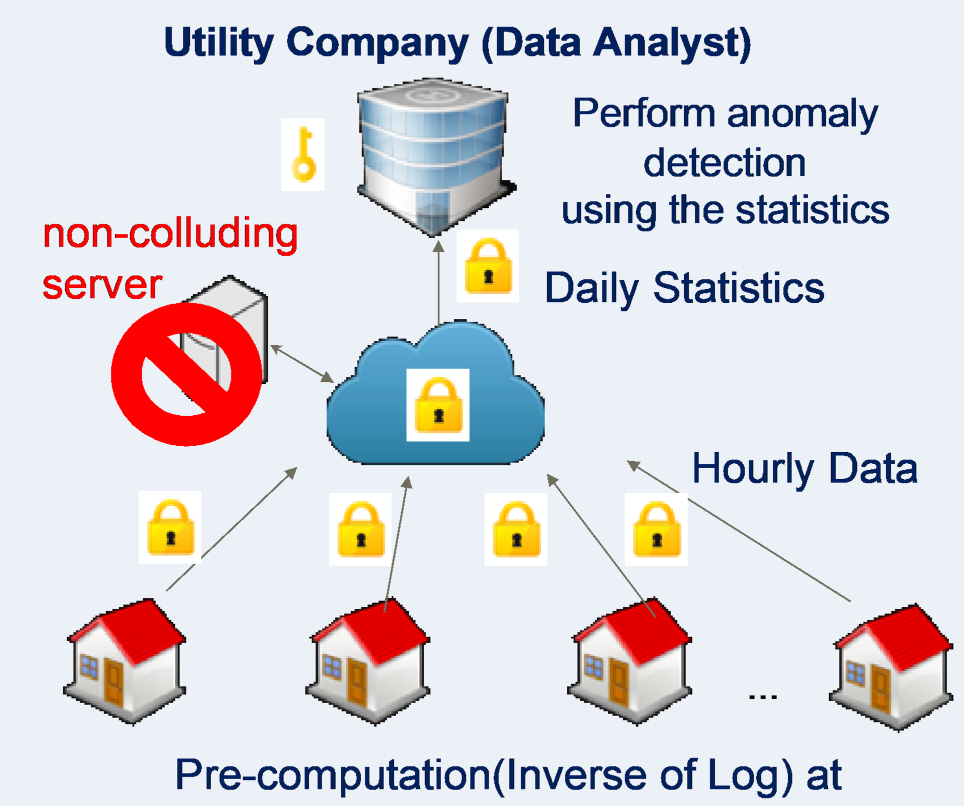
Micro-Level Detection: Efficient long short-term memory (LSTM) based traffic predictor by modeling each road segment in large scale traffic network as a function of neighboring roads.

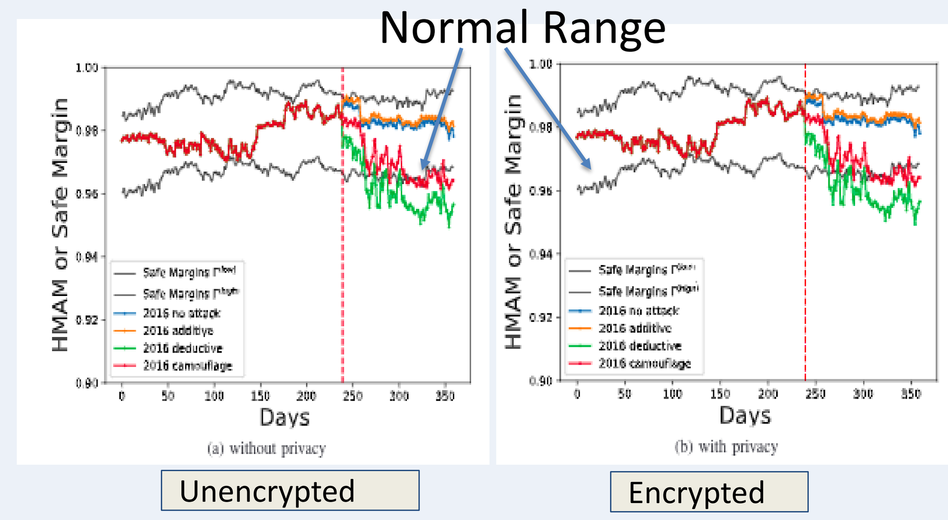
Robust Decisions Under Uncertainty



Anomaly Detection over Encrypted Data

- Adopted Approximate Homomorphic Encryption scheme (HEAAN) to leverage floating-point arithmetic (log computation) over encrypted data
- Anomaly detection algorithm over encrypted data w/o using non-colluding servers (more secure than Approach 1)
- Pre-computations of logarithm and its inverse at each household
- Optimized for FHE-friendly anomaly detection
- Homomorphic evaluation up to daily statistics that hide individual power consumption
- Almost same accuracy over both encrypted and unencrypted methods (possible to mitigate small accuracy error via post-processing)
- Server-side computation is feasible: 3.303 s/hour (each hourly time-slot)
- **Next Challenges**
- Enhance table lookup method to adopt multiple values, and propose less-than comparison for input values to handle wide range of inputs
- Balance Privacy-Performance trade-off with quantification (e.g., FHE with Differential Privacy)





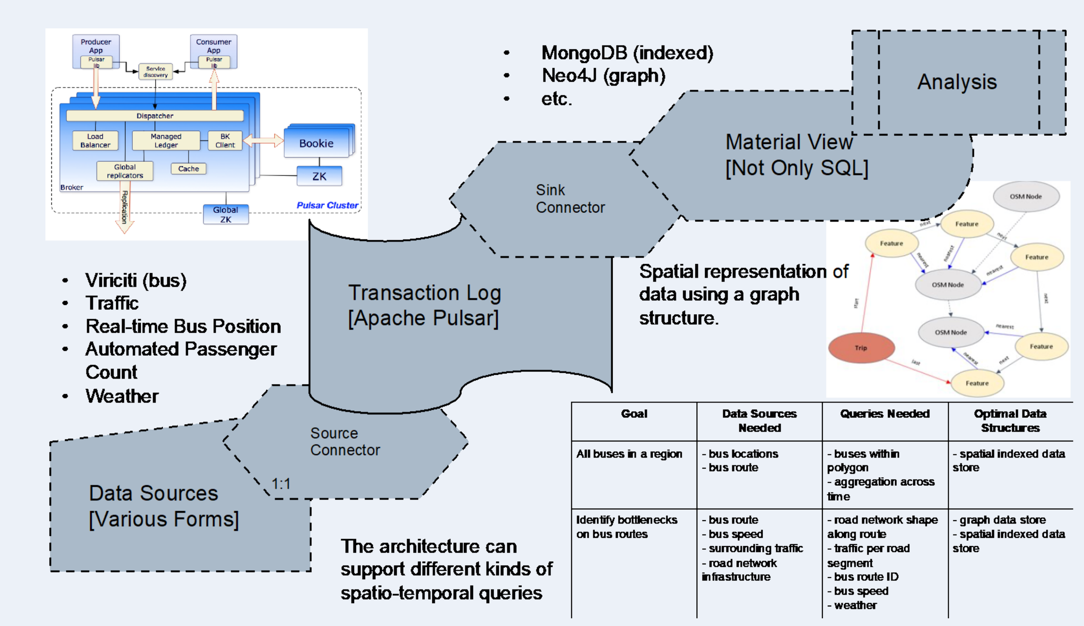
Ciphertext Size:
Household → Server: 2,270KB/hour
Server → Utility: 224KB/date

All experiments are with 136 households. Experiment is done with Intel Xeon CPU E5-1620 v4 @ 3.50GHz in single-threaded mode.

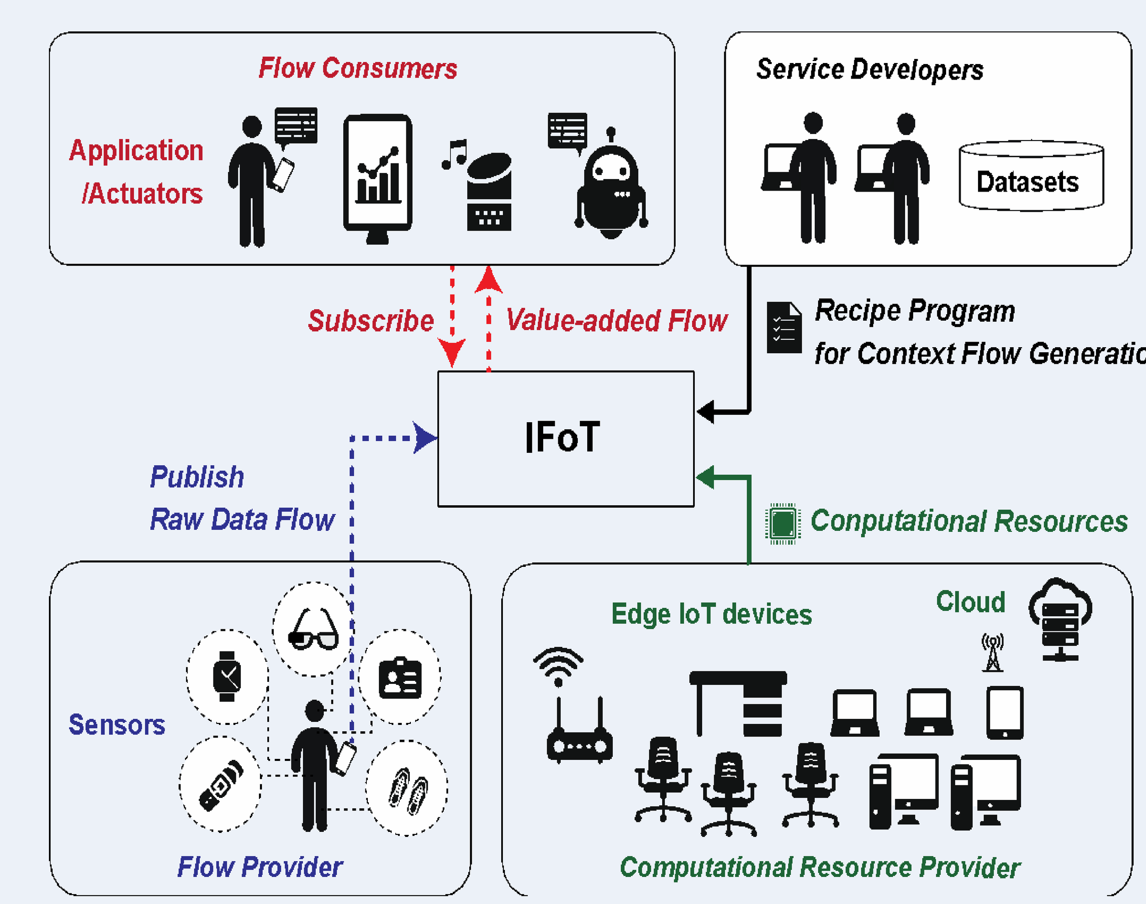
Distributed Processing and Data Store

Challenges

- How to build multi-domain architecture for smart mobility and smart energy?
- How and where to implement computations related to privacy, security, and trust?
- What are computational/resource challenges for scalability?



Distributed Data Store



Internet Flow of Things Middleware

- Designed a middleware architecture to assign tasks over IoT devices (e.g., RSUs, smart meters) taking into account required QoS level
- Implemented/ evaluated a prototype middleware
- Used Docker technology for easy deployment Developed Smart Transportation Service Emulation Testbed

Award #s: CNS-1818942 (Missouri Univ. of Science and Technology); and CNS-1818901 (Vanderbilt University)