SWATS: Timely, Accurate, and Reliable **S**teamflood and **WA**terflood **T**racking **S**ystem using Wireless Sensor Networks

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Goals / Problems Description

- **Goals**
  - Quickly detect, identify and localize anomalies that prevent planned delivery of steam or water to injection wells
  - Continuously monitor diatomite reservoir changes due to waterflood
- **Problems**
  - Automatically differentiating between anomalies in steam and water pipeline networks such as blockage, leakage, outside force damage and equipment malfunction
  - Detecting small changes in subsidence and uplift due to waterflood
- **Challenges**
  - Use inexpensive sensors, but provide reliable detection
  - Automatically distinguish between problems and false alarms
  - Providing continuous monitoring, quick report on problems, with little opex

Approaches for Anomaly Detection

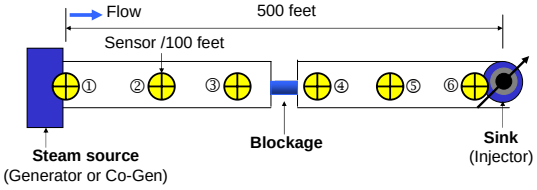
- **Classification of anomalies**

Events to detect		Where to put sensors	Reasons of events
Problems	Blockage	Splitigator, choke	Scale, left over after construction
	Leakage	Splitigator, junction	Pipeline corrosion, junction loose
	Outside force damage	Near roads or obstacles	Earthquake, stone
	Equipment breakdown	Generator, Splitigator, choke	Generator breakdown, Splitigator malfunction
False Alarms	Downhole pressure change	Injector	Vertical permeability, geological formation, heterogeneity
	Phase splitting at piping trees	Pipeline branches	difference in steam quality between upstream and downstream of branches
	Change in steam supply	Generator	Generator outage for scheduled maintenance
	Change in steam quality	Inlet of pipeline, Before and after Splitigator, Pipeline elevation	2-pahse transient property of steam, Pipeline elevation, generator turns on
	Sensor noise and faults	A pair of close-by sensors in the middle of pipeline	Inaccurate and unreliable thermometer, pressure meter
	Environmental reasons	A pair of close-by sensors in the middle of pipeline	Ambient temperature

- **Why difficult?**
  - Low-cost sensors can be unreliable and inaccurate
  - False alarms can be mistaken for real anomalies
  - Must understand topological effects of pipeline
  - Must understand transients in steam and waterflood
- **Overall approaches**
  - Utilize multi-modal sensing, multi-node collaboration
  - Exploit spatial and temporal correlations in multiple sensors, e.g., triggered by the same event
  - Create ***rule-based decision tree algorithm*** running on distributed sensors
- **Anomaly detection algorithm**
  - **Single-Node Processing**
    Sensor readings validation
    Noise reduction
    Event detection – *do I see a problem?*
  - **Multi-Node Collaboration**
    Multi-sensor validation – *faulty sensors?*
    Problem identification – *anomaly or false alarm?*
    Problem localization – *where is problem origin?*

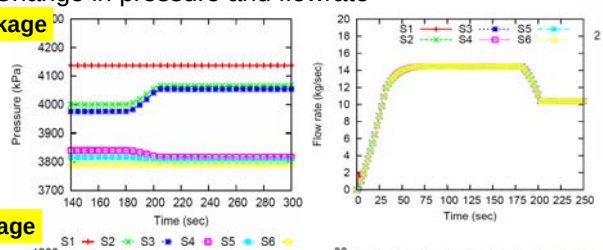
Preliminary Simulation Results

- A blockage scenario in a simple topology

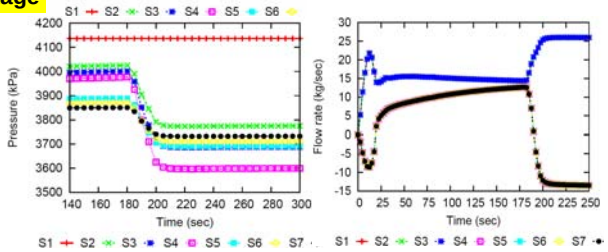


- Change in pressure and flowrate

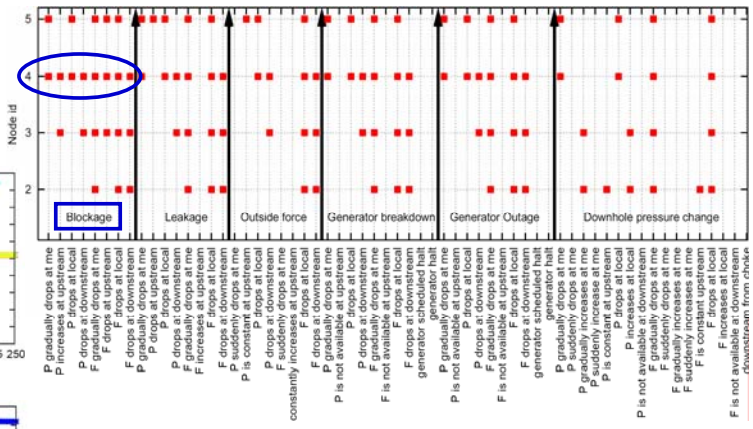
Blockage



Leakage



- Correctness of identification and localization
  - Node 4 correctly identified and localized the blockage. Red dot indicates corresponding predicate (P is pressure and F is flowrate)



- Summary of results
  - Identifies and localizes pipeline anomalies fast and correctly
  - Results in a negligible reduction on correctness, timeliness, and robustness with noise in flow
  - Show the potential of SWATS algorithm to improve the current SCADA system

Photo credit: AP Photo, E&P Magazine, Taylor Valve Technology DCOSS, June 2009