RISKNOUGHT: A Cyber-Physical Stress-Testing Platform For Water Distribution Networks

D. Nikolopoulos¹, G. Moraitis¹, D. Bouziotas², A. Lykou¹, G. Karavokiros¹, C. Makropoulos¹,²

(1) School of Civil Engineering, National Technical University of Athens
(2) KWR, Water Cycle Research Institute
Cyber-Physical Systems (CPS)

Systems with 2 layers:

• Physical Processes

• Control, Communication, Computation
Emerging threats on CPS

- CPS susceptible to a wide range of cyber, physical or a combination of attacks (CPA)
- Famous examples of cyber-attacks to CPS:
  - Stuxnet worm that targets SCADA units
  - Hacking of Maroochy Shire WWTP

CS 5032 Case study Stuxnet worm, 2013

CS 5032 Case study Maroochy breech, 2013
Water CPS as targets?

WDNs are a prominent critical infrastructure (CI) target!!! (ICS-CERT 2016)

Cyber attack incidents in USA, 2015 (DHS, 2016)
Existing (limitations of) CPS simulation tools

- Emulators of SCADA systems (e.g. OMNeT++, NS3) or Virtual Machines (VMs)
  - Precise representation of the cyber layer
  - Difficult interconnection with physical processes
  - Simulation of cyber-attacks is not straight-forward (penetration testing)
- EPANET-CPA (Taormina et. Al, 2017)
  - Influential work on WDN CPS systems
  - Depends on EPANET control logic
  - Representation of the information flow of the cyber layer, however options are limited
  - No quality modelling
RISKNOUGHT modelling platform

\textit{risk + nought = “to risk nothing”}

- RISKNOUGHT aims to be a complete modelling framework for water systems cyber-physical stress-testing and part of risk management of water utilities
- Ability to simulate the flow of information within the cyber layer (SCADA) and the interconnection with physical processes (hydraulic model)
- Control logic of the WDN is explicitly formulated
- Hydraulics are solved interactively with EPANET model
- WNTR python package (Klime et al., 2017) is utilized, as it couples EPANET with Pressure Driven Analysis equations
- Water quality modelling is handled with EPANET-MSX extension (reactive and conservative species)
RISKNOUGHT cyber layer model
RISKNOUGHT cyber-physical loop
RISKNOUGHT modelling capabilities

- Modeling of various sensors exposing various hydraulic aspects, such as:
  - tank level
  - node pressure
  - link velocity
  - link flow
  - concentration of a species etc.
- Actuators acting on:
  - pumps
  - valves
  - isolation of pipes
  - flushing units /hydrants (quality related actuators) etc.
RISKNOUGHT modelling capabilities

- Simulation of acknowledged signals (ACK) behavior and reporting of remote actuators
- Augmenting EPANET control logic based on complex rules, past timeseries (Historian unit), quality related controls
- Simulation of interconnecting PLCs, Master-Slave protocols, autonomous operations of PLCs, multiple distributed SCADA systems on the same WDN
- Alerts, flags and warnings on SCADA & HMI (human–machine interface) level
- Sensor/actuator manipulation/malfunction, DoS attacks on SCADA/PLCs and connections, chemical/microbial attacks
- Communication link attributes (e.g. fiber, wireless etc.)
- Pipe endurance ratings, simulation of bursting, leaks etc.
RISKNOUGHT interface (work in progress)
Benchmark network: C-Town

- Based on a real-world medium sized network (Ostfeld et al, 2002)
- 388 demand nodes, 7 tanks, 11 pumps, 4 valves
- One source of drinking water
- Some branched service areas
- Controls based on tank levels
Attack scenario #1

- **Type**: Manipulation of sensors
- Attacker manipulates readings of two different sensors (different start/end/durations and some overlap in the two cyber attacks).
Attack scenario #2

- **Type:** Exploitation of actuators
- Attacker exploits a vulnerability in the PLC controlling all pumps in the network and issues repeating random commands (open/close) for an extended period of time, actuators send ACK signals.
Attack scenario #3

- **Type**: SCADA DoS Attack, Master-Slave protocol
- Attacker performs a DoS attack on the SCADA. PLCs have a Master-Slave SCADA communication protocol, so controls cannot be enabled and sensor readings are not registered. Timing is not perfect for the attacker.
Attack scenario #4

- **Type:** SCADA DoS Attack, Master-Slave protocol, insider knowledge
- Attacker performs a similar DoS attack on the SCADA with a Master-Slave protocol and knows what time the attack consequences will be critical.
Attack scenario #5

- **Type:** SCADA DoS Attack, Autonomous PLCs, insider knowledge
- Same as scenario #4, but the protocol is not Master-Slave for all PLCs. Some can operate autonomously in case connection to SCADA is lost (semi-distributed control protocol).
Benchmark network: Net 1+

• Simple network model for quality stress-testing: one source, one tank, one pump, 8 demand nodes
• Augmented SCADA controls with actions on the event of contaminant detection
• Single quality sensor at NODE 10
• If an anomaly is detected, PIPE 10 is isolated and the Tank valve is closed
Attack scenario #6

- **Type:** Contaminant injection, attack on quality sensor
- Attacker contaminates the water distribution system and at the same time hacks the connection between the sole quality sensor of the network. The quality sensor reports “normal” readings.
Attack scenario #7

• **Type:** Manipulation of quality sensor
• Attacker exploits vulnerabilities and manipulates the readings of the sole quality sensor in the network in order to fake a severe contamination event, leading to the closing of the main distribution pipes.
Conclusions

• Water CPS are CIs vulnerable to a multitude of cyber-physical threats
• RISKNOUGHT is able to simulate both the interplay between the cyber and physical layers of a WDN
• RISKNOUGHT models a multitude of cyber-physical threat events and also risk reduction measures
• Bridge the gap between precise emulation of SCADA systems and simple simulation of control logic rules of hydraulic operations
• Support for extensive water quality modelling with the EPANET-MSX extension

RISKNOUGHT is under active development and will be expanded with more functionality soon!
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References

Thank you for your attention