Y9.ET1.1 Cyber-Physical Implementation of MQTT as a FREEDM Smart Grid Interface

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OBJECTIVE

- To design, implement and analyze the MQTT protocol as a secure communication interface in the FREEDM smart grid system.

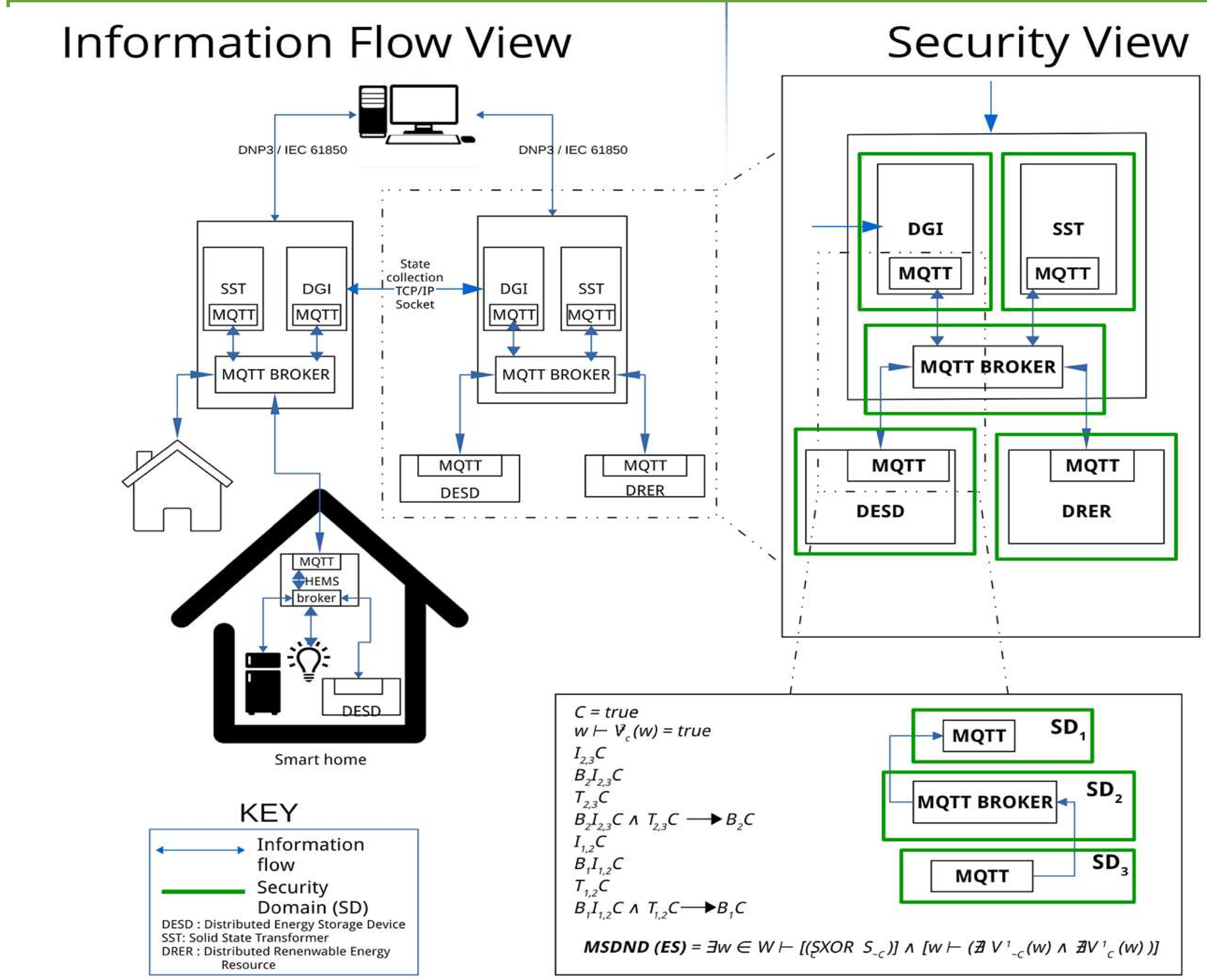
BACKGROUND

- Distributed Grid Intelligence (DGI) delivers and manages electric power
- The DGI modules employ modular adapters to interact with devices in the smart grid over different interfaces.
- MQTT (Message Queuing Telemetry Transport) is a machine-to-machine connectivity protocol designed as a lightweight messaging transport.
- MQTT uses a publish/subscribe format for message transmission over low bandwidth, highly latent networks of remote devices with constrained fragile connections.

APPROACH

- This project uses a device adapter approach to provide the multiple device communication interfaces.
- On the FREEDM system, a DGI node is run parallel to a MQTT broker that facilitates the publish/subcribe format.
- A DGI node in the system runs a C++ based MQTT adapter that sets up a TCP/IP connection to the MQTT broker.
- This MQTT adapter, and all other MQTT devices in the smart grid, subscribes to MQTT topics based on device types.
- Devices publish their respective energy infrastructure which are received and processed by a DGI node.
- Commands are periodically generated by the DGI to specific device topics.
- With these two lines of communication, an interface is established.

IMPLEMENTATION



RESULTS

- With this architectural design, we have been able implement to the MQTT protocol on a simulated FREEDM smart grid system with a DGI node, SST, DESD and DRER.
- Using MQTT's QoS (Quality of service) feature, we have been able to ensure message delivery in a smart grid.
- MQTT also provides a 'Last will' feature that notifies devices across the distributed system if any other device gets disconnected.
- The MQTT implementation maintains a continuous connection to the broker. This 'always-on' feature supports the real time and continuous objectives of the FREEDM system .
- With the above features , the switch from plug and play to MQTT has maintained the same level of simplicity but with a more functionality and efficiency
- Implemented in the Green Energy Hub to interface with real devices.

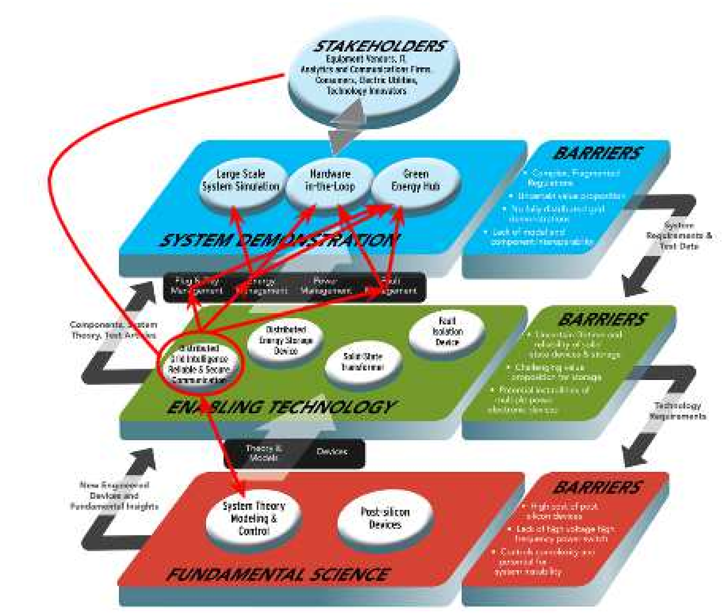
Cyber-physical security analysis

- We tested the integrity and confidentiality of the architecture using a cyber-physical tool called MSDND (Multiple Security Domains Nondeducibility).
- We determined the MQTT architecture to be MSDND secure. To be MSDND secure means, every device in the smart grid cannot evaluate the correctness of information from another device.
- While this seems plausible from a confidentiality point of view, for integrity, this leaves the system vulnerable to attack.
- An operator at a SCADA server would not be able to detect erroneous results, due to the singular information path. Coupling the integrity risk with the lack of end to end encryption, the MQTT protocol faces multiple distinct security vulnerabilities.
- However this analysis allows us to counter the multiple threats with the use of security invariant. The invariants provide other system entities i.e security domains with valuation functions to evaluate the correctness of information received.

LIMITATIONS

- Other than the error detection parity provided by TCP/IP, MQTT lacks security invariants to protect the system in case of a cyber-physical attack.
- The always-on MQTT connection, even when no messages are being transmitted, can be a drain on computational resources .

RELATIONSHIP TO THE STRATEGIC PLAN



CONCLUSION

- Despite the limitations, MQTT is still the stand out communication protocol in the IoT (Internet of things) realm. MQTT combines the ease of a plug and play protocol with resilient functionality.
- The ability to work with standards like XML, JSON and protocol buffers. With the above advantages, the MQTT protocol is a perfect fit for a device interface on a smart grid system like the FREEDM system.

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