U.S. DEPARTMENT OF ENERGY | OFFICE OF Cybersecurity, Energy Security, and Emergency Response

Scalable Quantum Cybersecurity for Energy Storage Systems (SEQCESS) Oak Ridge National Laboratory

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Cybersecurity for Energy Delivery Systems (CEDS) Peer Review

October 6-7, 2020

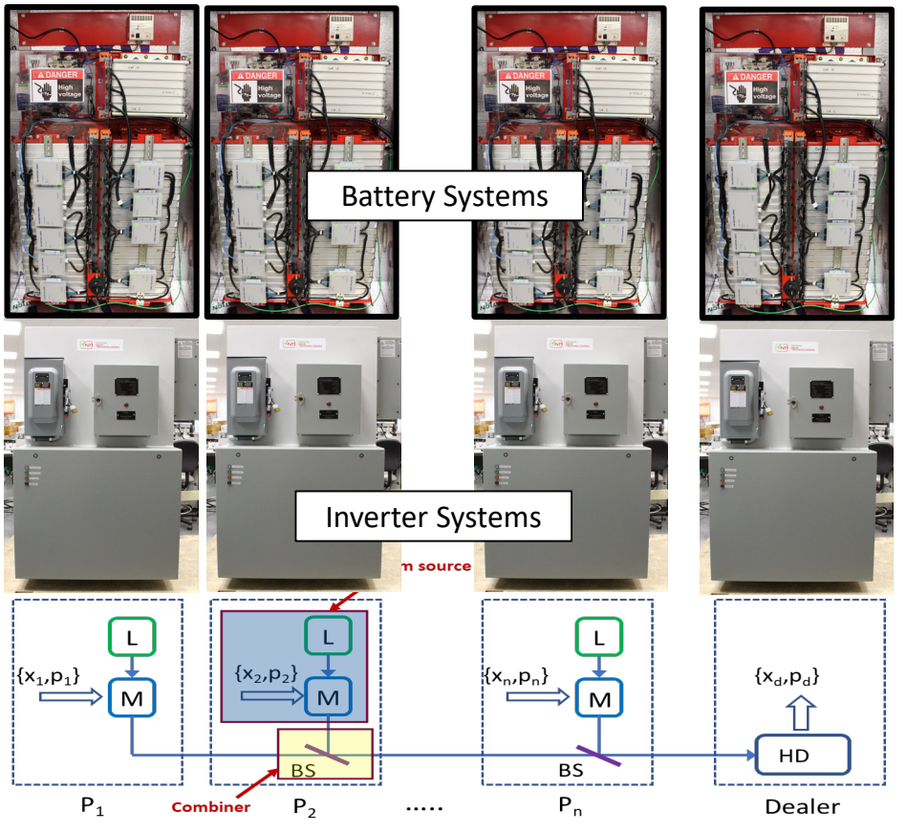
Scalable Quantum Cybersecurity for Energy Storage Systems (SEQCESS)

Objective

- Develop quantum communications interface to classical communications.
- Authenticate a single user to a single Distributed Energy Storage (DES) node.
- Enable single-to-many quantum secured communications to distributed DES nodes.

Schedule

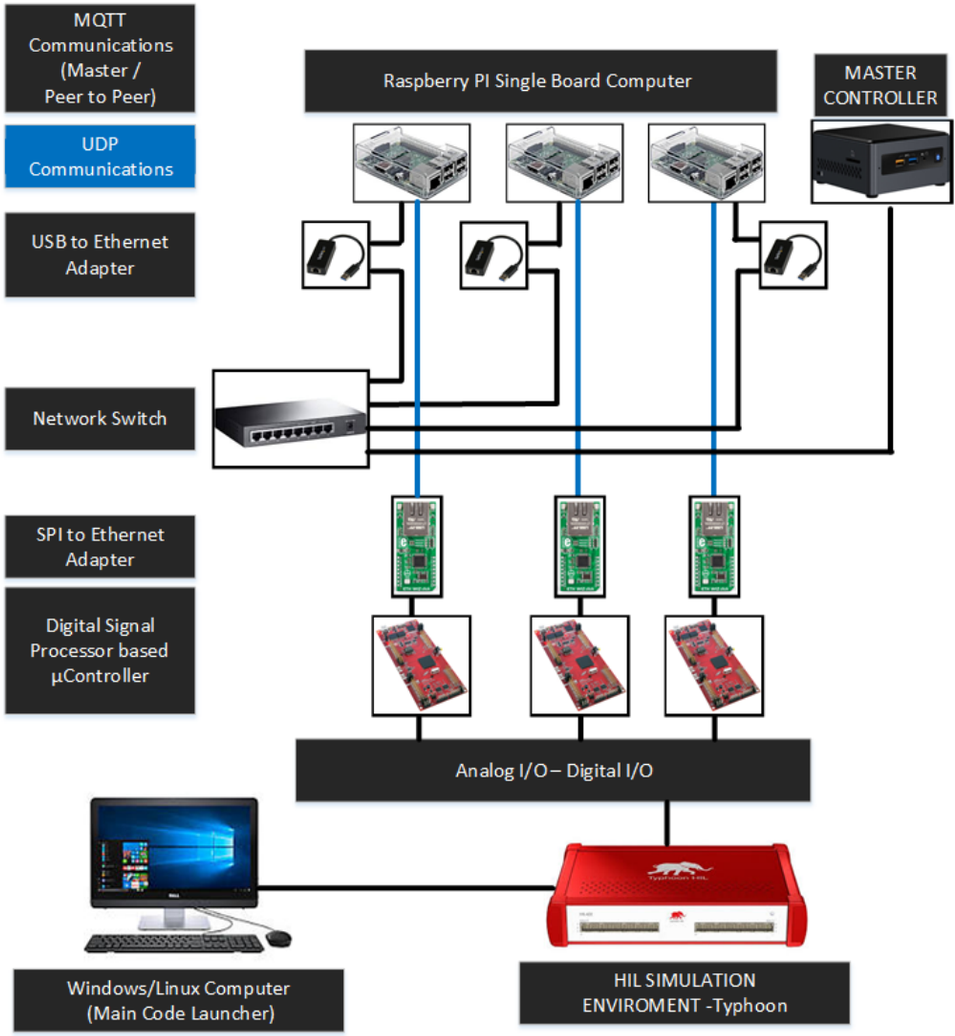
- 10/01/2019-09/30/2022
- Theme 1: Use commercial quantum key distribution for authentication (point to point).
- Theme 2: Develop new point-to-multi-point quantum protocols for authentication.
- Quantum-based long-lasting authentication will be interfaced to to the general energy SCADA communications.



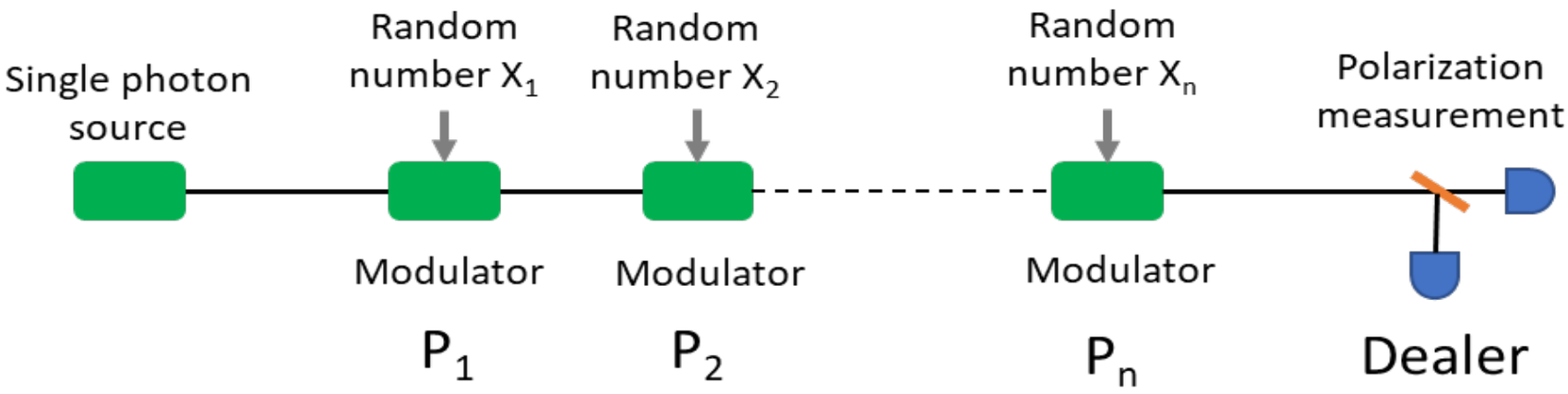
Total Value of Award:	**$3,194,000**
Funds Expended to Date:	**18 (38 committed)%**
Performer:	**ORNL**
Partners:	**EPB, Qubitekk, LANL**

Advancing the State of the Art (SOA)

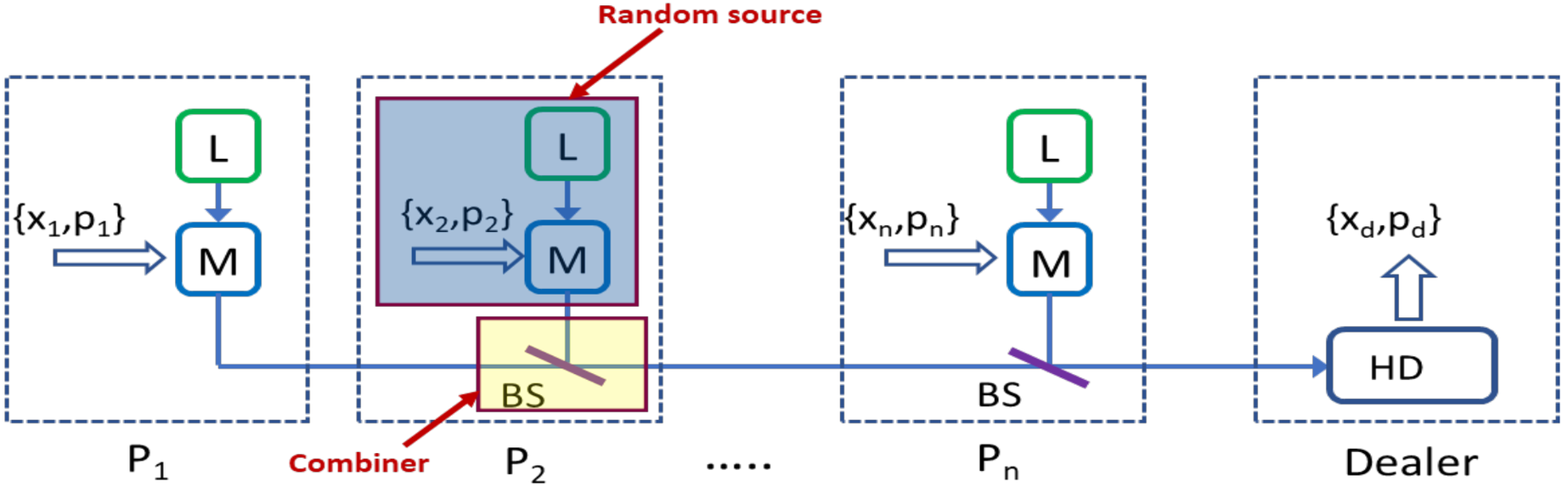
- "State of the art" ORNL Distributed Energy Storage (DES) communicates using Message Queuing Telemetry Transport (MQTT) publish/subscribe protocol.
- We are using quantum resources to build authentication into these communications.
- Authentication has "information theoretic" security – i.e., independent of computational sophistication assumptions, so it lasts lifetime of infrastructure.
- Messages remain in clear text so if anything breaks one can still see data.
- Strong authentication gives confidence data is genuine revealing adversarial manipulation.



Advancing the SOA: Secret Sharing



Problem: Trojan-horse attack—an adversary may send faked signals to the modulators and read out the encoded random number.



Solution: Remove modulator & inject quantum signal.

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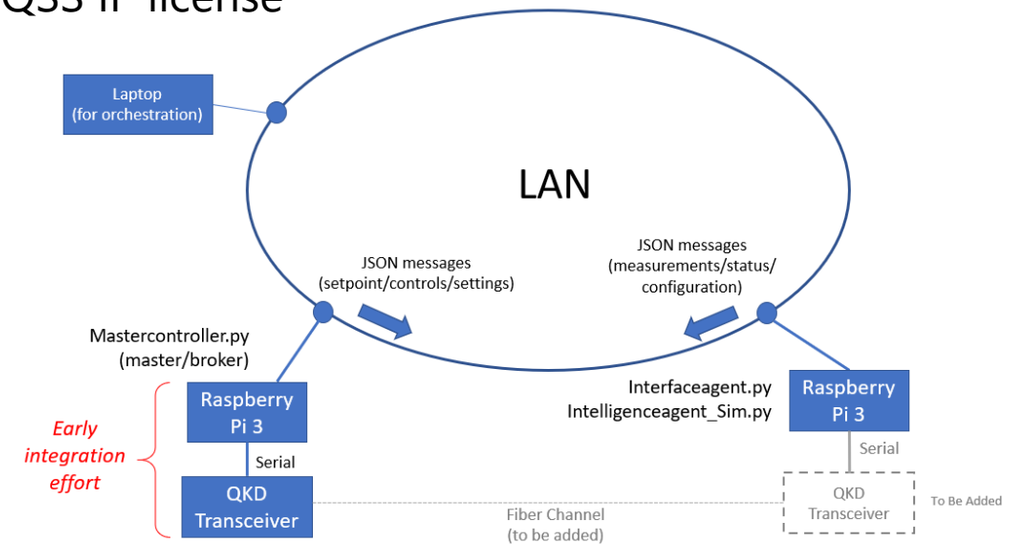
W. P. Grice and B. Qi, "Quantum secret sharing using weak coherent states", Phys. Rev. A 100 022339 (2019).

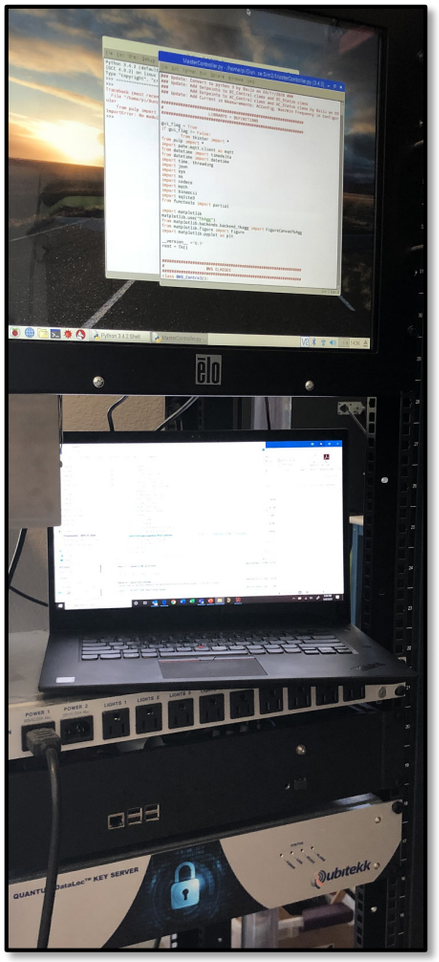
Progress to Date

Major Accomplishments

- Integration of ORNL emulators with physical QKD hardware (at Qubitekk).
- Integration of Qubitekk QKD emulators with ORNL hardware (at ORNL).
- Exploration of key transfer protocols and incorporation of keys into ORNL's lightweight authentication and encryption protocol.
- Construction of dedicated network for testing.
- Subcontracts in place September 2020.
- QSS IP license



Dedicated network at Qubitekk for integration testing.



Rackmount devices at Qubitekk for integration development

Challenges to Success

Challenge 1: COVID19 restrictions make it difficult to get into locations and slow collaboration

- Lab work moved to “shifts” to minimize people density.
- Focus on utility demo prep work so we are ready to go when a window of opportunity opens.
- Early focus on theory which could be done from home.
- Maximized remote work, both from home offices but also, by sharing resources between CA and TN.

Challenge 2: Subcontracting delays/personnel changes

- Started subcontracting process (SOW development) as soon as we learned of funding.
- Ordered required materials early.

Collaboration/Technology Transfer

Plans to transfer technology/knowledge to end user

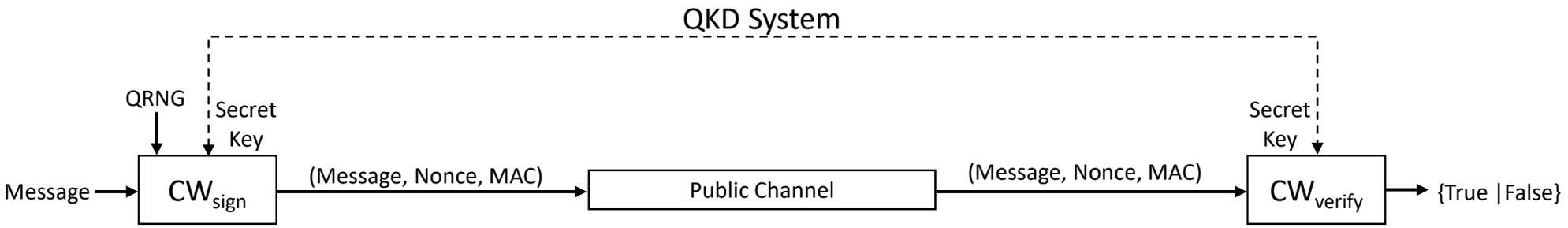
- Work with partners to directly transfer results.
- Quantum Tech Transition Website: https://quantumsciencetechnology.ornl.gov/technologies-available-for-licensing/
- Plans to gain industry acceptance: Yearly tests planned at EPB in Chattanooga & Red team review by LANL.
- Sector adoption can take place along with QKD system use.

Next Steps for this Project

Approach for the next year or to the end of project

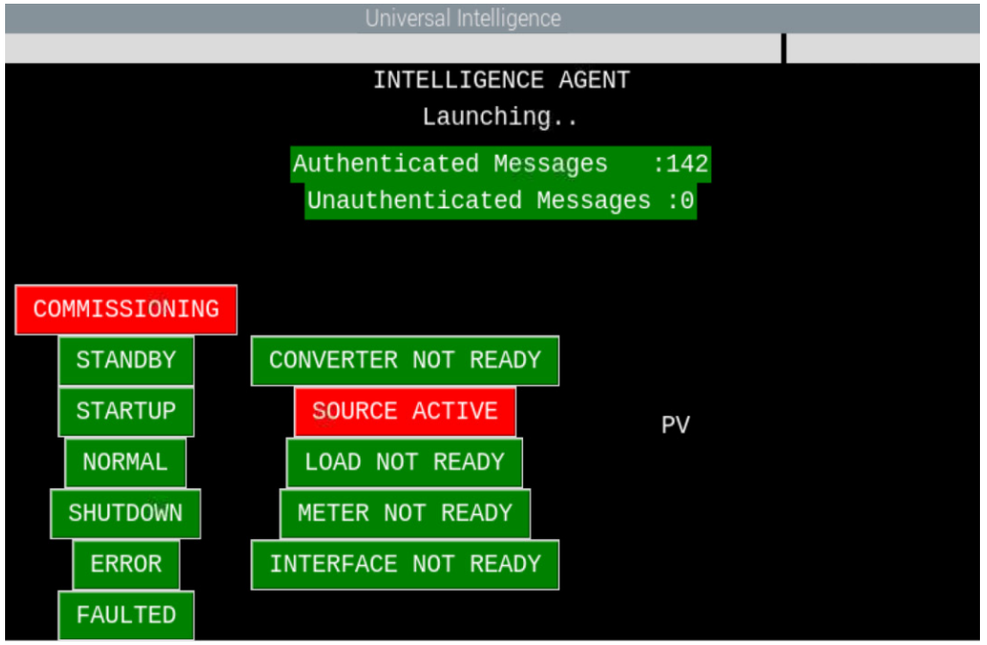
- Demo of Qubitekk keyed authentication of MQTT DES communications at EPB at the end of October.
- Develop Quantum Secret Sharing hardware with continuous variable encodings – good for networks with classical traffic.
- Develop Quantum Digital Signature System with Qubitekk Polarization Entanglement Hardware.

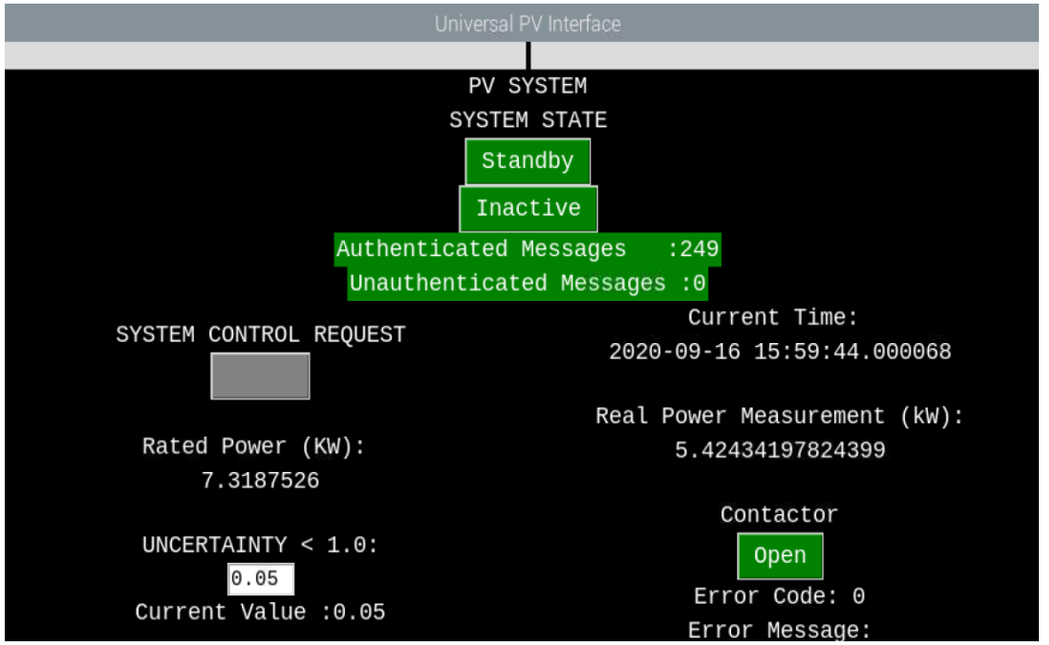
Signing and Verification



- **Key Management**
  - Retrieve key material as a string of bits.
  - Verify the key length is 256-bit.
  - Associate each key with an arbitrary identifier.
  - Create a key table with Boolean status flag.
- **Random numbers Management**
  - Retrieve random number from QRNG as binary file.
  - Process the large binary file to 128-bit chunks.
  - Associate each number with an arbitrary identifier.

Successful authentication of published messages





Match

```
Standby--PV/State--1600288314--7380
Key:    56031090556694191636151677483690230086325472504571419961418682364552695386879
Nonce:  de5ce87aa0a1a1fa6ece2769b8e79933
MAC:    4ce0281a85daea4d2a0d9f620c5711a9
```

Publisher

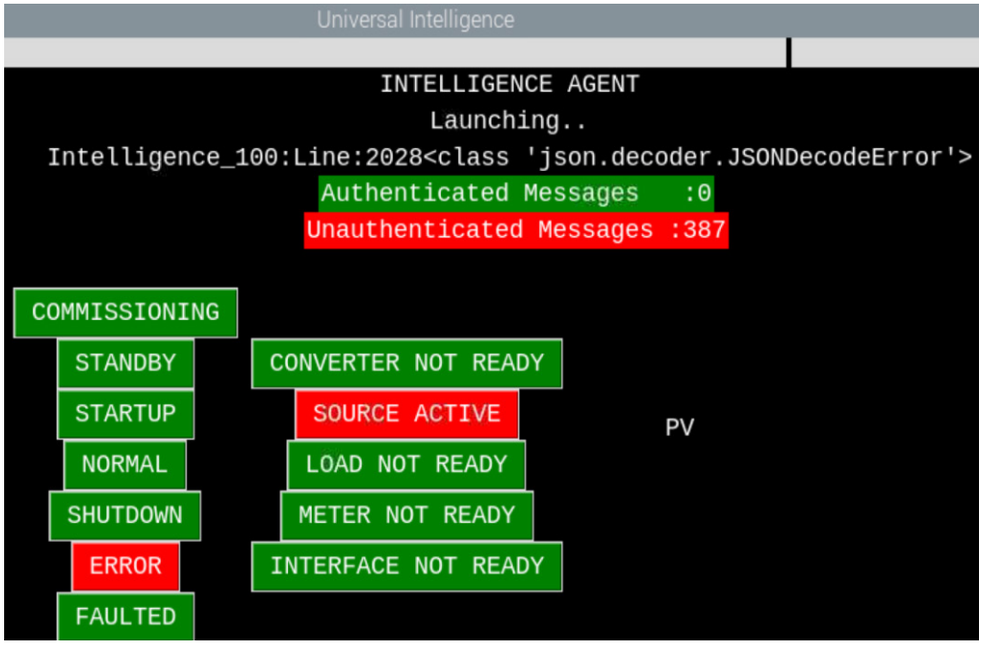
```
Standby--PV/State--1600288314--7380--de5ce87aa0a1a1fa6ece2769b8e79933--4ce0281a85daea4d2a0d9f620c5711a9
Key:    56031090556694191636151677483690230086325472504571419961418682364552695386879
Nonce:  de5ce87aa0a1a1fa6ece2769b8e79933
MAC:    4ce0281a85daea4d2a0d9f620c5711a9
The message is authentic
```

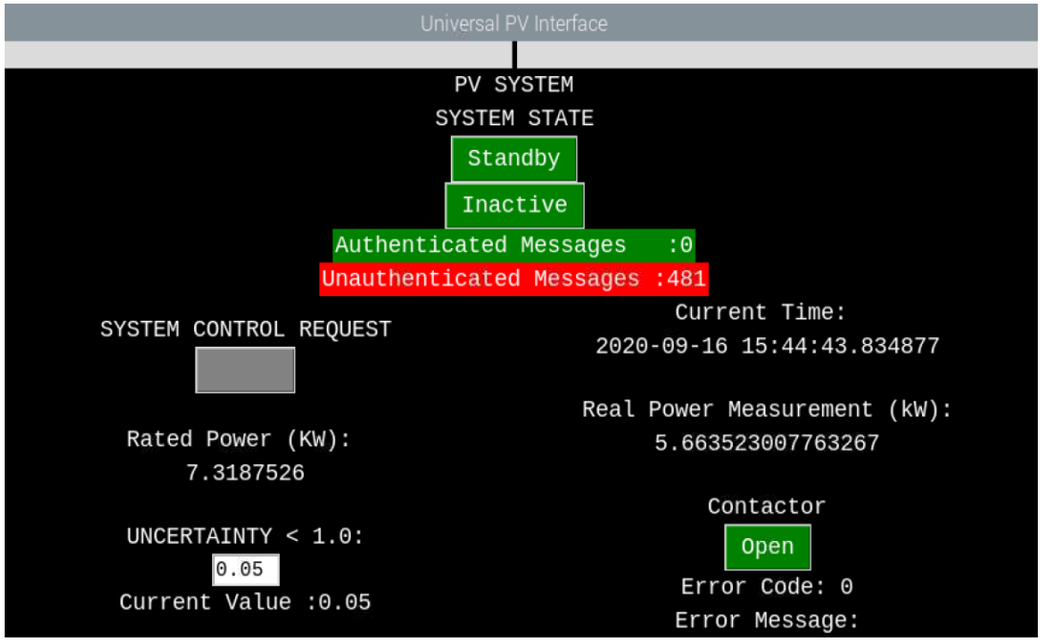
Subscriber

Authenticated

Publisher and subscriber share **valid** secret keys

Unsuccessful authentication of published messages





Invalid

```
Standby--PV/State--1600284321--170
Key:    377697945612338772585243686256097708172547655914783199952842424936382255209 40
Nonce:  55aebd3aa526b0bc9fb2ab832893063c
MAC:    adf924105fd72baab413e04efb1eabe5
```

Publisher

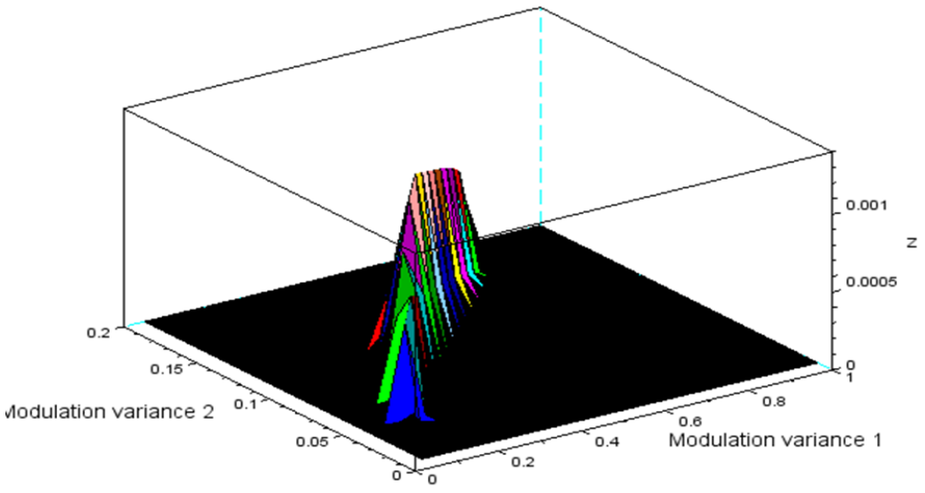
```
Standby--PV/State--1600284321--170--55aebd3aa526b0bc9fb2ab832893063c--adf924105fd72baab413e04efb1eabe5
Key:    165753795101510001037640841543139715020911952655967189114173746786460345980 33
Nonce:  55aebd3aa526b0bc9fb2ab832893063c
MAC:    adf924105fd72baab413e04efb1eabe5
Error: cannot authenticate the message!
```

Subscriber

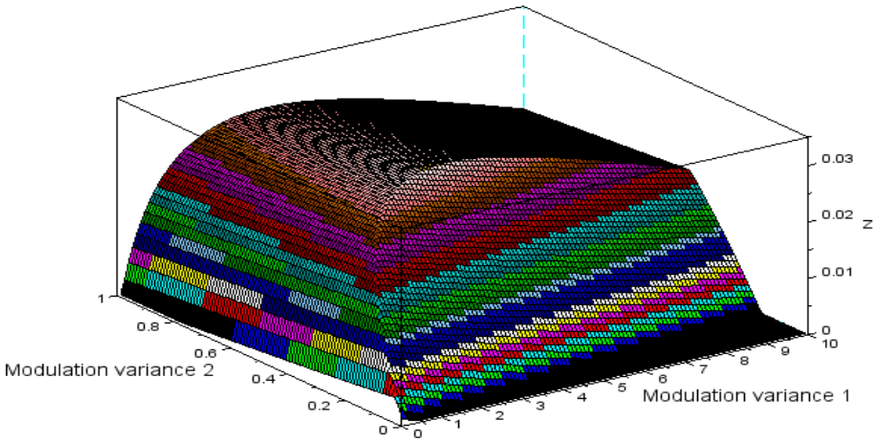
Unauthenticated

Publisher and subscriber share **invalid** secret keys

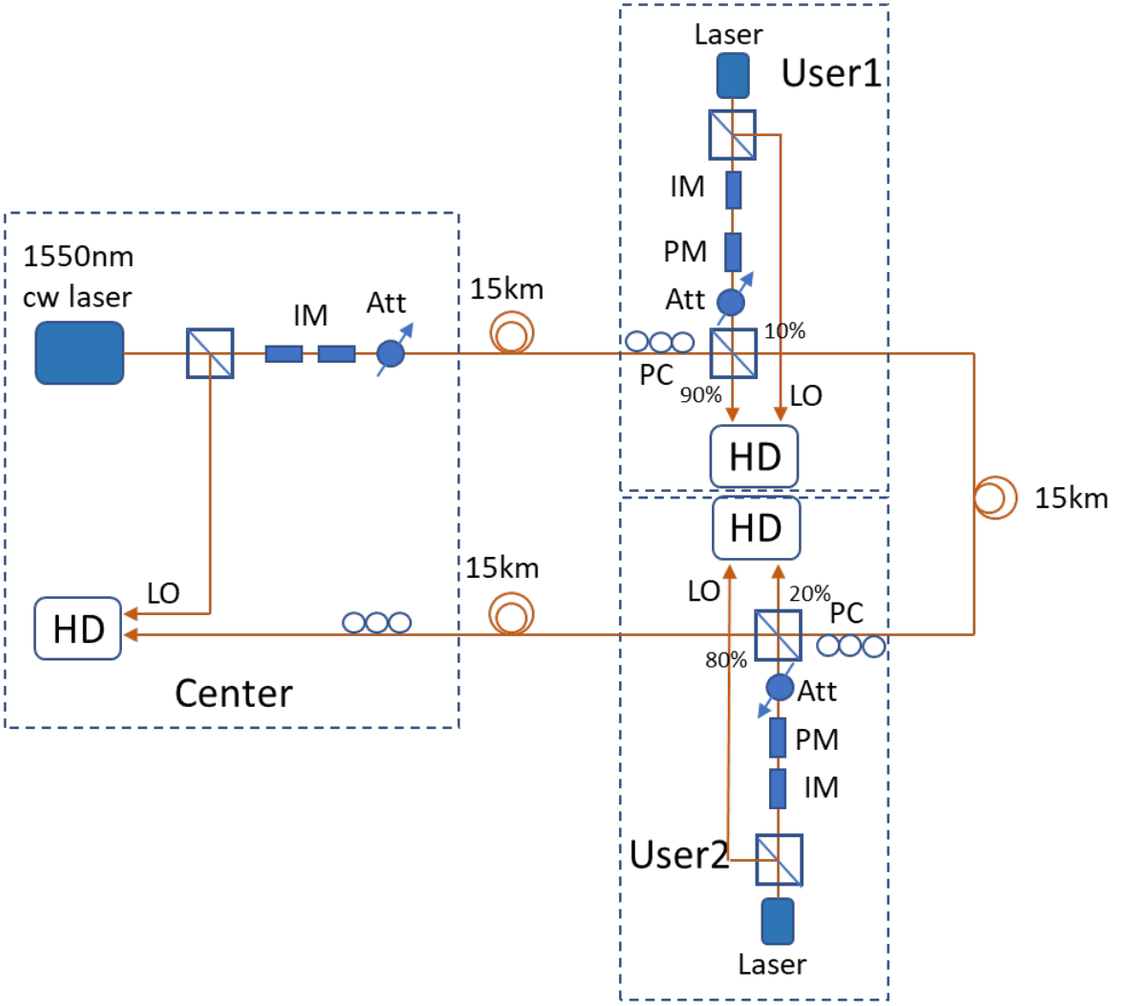
Three-party CV QSS design and simulation



Simulation results with 150KHz laser



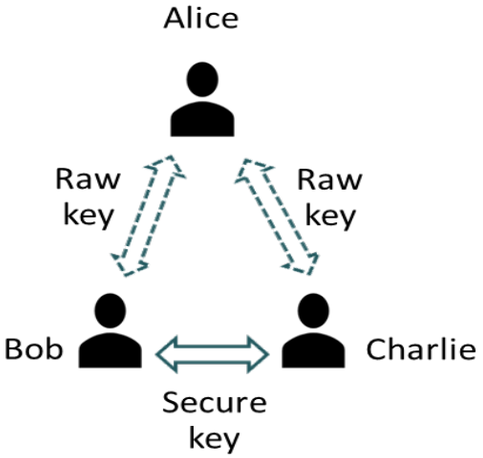
Simulation results with 10KHz laser



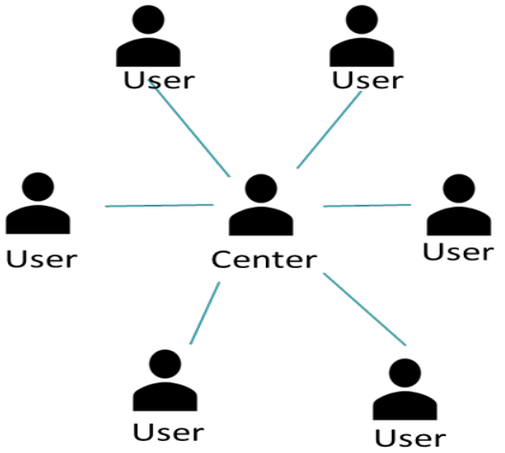
Proposed setup

Quantum digital signature

- Digital signatures can offer authenticity and integrity, non-repudiation, and transferability;
- Classical digital signatures are based on public key crypto, such as RSA, so cannot provide information-theoretic security (ITS);
- Quantum digital signature (QDS) can have proven security and can be implemented using QKD infrastructure;
- Existing QDS protocols lack the feature of universal verifiability and cannot completely replace digital signatures based on PKI.



Prior Art



Proposed scheme using EPR source