ITU Workshop on Quantum Information Technology (QIT) for Networks

Shanghai, China, 5-7 June 2019

Session 1: World tour of Quantum Information Technology Development

Takeaways and/or Conclusions

1. China:
   - Q computing: optical, superconductor, ultra-cold atoms
   - Q communication: national Q backbone (Beijing – Shanghai 2000km, 32 trusted relays); Q satellite 'Micius' (QKD, Q teleportation, Q entanglement); Quantum Internet (Q constellation + Fiber Q com infrastructure); Intercontinental QKD (Vienna – Beijing)
   - Q metrology: navigation, opitical clock, atomic gyroscope, atomic gravimeter, single photon LIDAR
2. European QT-Flagship: 1b euro/10 yrs, 20 projects in first three years 2018-2021: Q comp, simulation, communication, sensing
3. Canada: research in major universities: Q networks, e.g. Q teleportation over metro networks, Q transduction, Q memory, theory & experiments in network security + architecture
4. Russia:
   - Data Economy government program 2019-2024 includes quantum technologies
   - Various Q network testbeds;
   - Research centers in Moscow, St Petersburg, Kazan
   - transcontinental line in Russia to unify China and EU
   - QKD in space in preparation (satellite launch 2023)
5. Japan:
   - 5th Science and Technology Basic Plan (2016-2022)
   - Society 5.0 integrates cyberspace and physical space
   - Q-secure cloud by various companies and universities
   - Q Leap Flagship program: superconducting Q Comp; Q sensors

Takeaways and/or Conclusions

1. Korea: Q-ICT roadmap (Dec 2018): Q-ICT = Q comms + Q comp + Q sensors
2. CERN: IDEASQUARE: bring together researchers and industry on topics such as Q technology, Q applications, Q networking
3. USA: Dec 2018: National Quantum Initiative to accelerate research and development in the technology over the next 10 years. The law authorizes $1.2 billion over five years for quantum-related activities across the federal government.

Suggestions to ITU

- ❑Numerous testbeds in operation in various countries
- ❑QKD standardization and certification are in development at national, regional and international levels.
- ❑ITU, UN specialized agency for ICTs, is a uniquely positioned platform to gather QIT experts in one place and work together

Session 2A: Frontier Research of Quantum Computing

Takeaways and/or Conclusions

1. There is no good understanding of practical problem that face industry.
2. Quantum and classical advances are needed
3. In quantum, there are more advantages then speed, it is robustness to noise
4. There are poor communication between developers and users in the scientific world

Suggestions to ITU

- Establish a framework to collaborate more with researcher and quantum experts from both Industry and Scientist sides to identify concrete applications of QC
- A good understanding of practical problem faced in industry is essential to push the barriers of classical way of solving practical problem and exploring the quantum way of working on these problems
- Set up a a platform that opens channels between developers (i.e. who publish algorithms, provide support, manage updates) and users (search for solutions, run algorithm, give feedback)

Session 2B: Quantum Computing Industry Perspective

Takeaways and/or Conclusions

1. Progress in quantum computing will likely be accelerated significantly
2. The commercial applications of QC are rooted in many technical areas
3. There is a lack of funding for early stage quantum commercial applications
4. Need for more algorithmic innovation to maximize the use of Noisy Intermediate-Scale Quantum
5. Need for a hybrid model that maximize the use of both quantum and classical processors

Suggestions to ITU

- Establishing a framework that put together Software engineering expertise, Quantum algorithm designer and developers, quantum hardware engineers and experts in the application domain of quantum computing
- Necessity for collaboration between public sector and private sector to sustain the field in its early stage

Session 2B: Quantum Computing Industry Perspective

Takeaways and/or Conclusions

6. QC is useful for breaking code, for chemistry problem for optimization problems
7. Necessity to build networks of quantum computers

Suggestions to ITU

- ❑ Establish best practice (standards) to help people who don't have knowledge about quantum computing to build on top what has been already built to not invent the wheel again
- ❑ Highlight the importance of general purpose of quantum computing
- ❑ There are needs for standards :
  - ❑ to support heterogeneous networks
  - ❑ routing and transmission control for quantum messages
  - ❑ interoperability between different device technologies

Session 3A: QKD Technology

Takeaways and/or Conclusions

1. Fundamental technology for QKD are mature. High rate, long distance are well achieved.
2. Quantum network design (latency, reliability, scalability, cost, security, key consumption etc.) are important issues that need to be studied.
3. Different protocols like Continuous-variable (CV) QKD are alternative solutions in special scenarios.
4. Security issues including imperfections are addressed seriously and are well analyzed, which helps to remove all known attacks.

Suggestions to ITU

- ❑ Establish quantum network group for further intensive research
- ❑ Gap analysis of standards landscape is needed for techniques tailored for quantum network like QKD, key management etc.
- ❑ New quantum network architecture and applications need to be addressed.
- ❑ User cases and application scenarios of quantum network need to be addressed.
- ❑ Standards in QKD and quantum information network are emerging and timely.

Session 3B: QKD Applications

Takeaways and/or Conclusions

1. QKD has many applications in the fields of finance, state grid, etc. Although not yet very extensive, these applications have demonstrated QKD's potential in guaranteeing quantum-safe security for important infrastructures
2. The development of QKD application needs to be actively integrated with basic communication networks
3. The development of QKD application requires active testing and evaluation work conducted by the third-party
4. Standardization work is urgently needed on the topic of QKD test and evaluation, QKD's integration with classical communication networks and information security technology, etc.

Suggestions to ITU

❑ Accelerate the development of QKD-related standard in ITU

❑ Investigate the feasibility and means of integrating QKD applications with existing network standards

❑ Collaborate with other standards organizations like ISO/IEC JTC 1, ETSI in pushing forward QKD standardization work

Session 3C: QKD Networks

Takeaways and/or Conclusions

1. QKD networks have been implemented worldwide, from demonstrations to relatively large scale network in real world.
2. Trusted relay are widely considered in practical QKD networks.
3. New concepts such as SDN QKD networks have been implemented and tested.
4. Security, interoperability, scalability and robustness are important aspects for QKDN.
5. Quantum cryptography technologies can be combined with 5G network.
6. Co-fiber transmission efficiently reduces costs in QKD network deployment.
7. Satellite ground integrated QKD network will be the next step.

Suggestions to ITU

- ❑ Standardizations are needed in different layers of QKD network.
- ❑ QKD network needs standardizations to support its practical implementations and applications.
- ❑ ITU needs to gather experts from quantum, network, security etc. to work together on QKD network standardizations.
- ❑ ITU needs to coordinate standardization works of QKD network from different perspectives within ITU SGs and with other SDOS.

Session 3D: QKD Products

Takeaways and/or Conclusions

1. Standards important for broad deployment of products across QIT
2. Customers look for security assurance and standardized interfaces
3. Desire low barrier to entry for “quantum-ready” applications
4. QRNG is critical in many apps
5. Many architectures for co-existence with classical data – must consider existing optical comm. standards

Suggestions to ITU

- ❑Increase cooperation
- ❑Limit number of meetings and duration (agenda in good time)
- ❑Engagement with ITU members with complimentary experience

Session 4: Quantum Metrology

Takeaways and/or Conclusions

1. The best gravity meter is based on quantum interference $10\mu g/\sqrt{Hz}$. Gravity meter and accelerometer have a market for billions Yuan.
2. LIGO is the most sensitive interferometer
3. Single photon lidar goes to 45 km, which has applications in aerial photograph and remote sensing.
4. 6/7 elements in SI is based on time and quantum. The new definition of second based on cold atomic clock is scheduled for 2026.
5. Single photon lidar has the advantage in remote sensing of air pollution and wind speed due to long range and eye safty.

Suggestions to ITU

1. Considering the international standardization of quantum metrology

Session 5: Quantum Information Network

Takeaways and Conclusions

1. Rapid development of earth-based quantum-satellite stations on land and sea and introducing geo satellite for all-day communication capability.
2. Projected huge growth in consumer demand for quantum cryptography.
3. Quantum repeater technology is now at a basic-science development stage, and cold atoms offer a promising direction.
4. New quantum key distribution protocols are being developed so both mature and nascent protocols need to be considered in planning standards.

Suggestions to ITU

- ❑ Satellite- and fiber-based quantum communication are based on mature technologies and have customers so standardization should be considered.
- ❑ Consider the balance between mature and nascent technology and the timelines in planning standards development.
- ❑ Develop standards in this field as needed.

Session 6A: Global (QIT) Standardization - Presentations

Takeaways and/or Conclusions

1. QIT is of strategical importance to digital economy and global development.
2. QKD will soon become integral part of digital infrastructure. It is much more cost-effective if QKD is built in (parts of) the network - ‘SDN is both the enabler and user of QKD’
3. QIT is a complex subject. Fast growing market needs test and certification. Standards contribute to innovation
4. Standardization has started international SDOs, and accelerated esp. in past 2~ yrs
5. Concern on overlapping/duplication of effort on standardization

Suggestions to ITU

- ❑ Develop basic standards on terminology, framework, architecture, requirements, use cases, … to codify and share knowledge/understanding

Session 6B: ITU QIT Standardization - Panel discussion

Takeaways and/or Conclusions

1. ITU introduction:
   - UN agency, 193 member states, 700+ company, 150+ Univs
   - 6 official languages
   - ITU focus group: open to non-members
2. ITU is an fair and transparent int. org
3. Common standards of ITU/ISO/IEC: 10% of ITU standards
4. Good collaboration with ETSI:
   - ETSI INT and ITU-T SG11
   - ETSI EE and ITU-T SG5: common experts, co-located meetings, common outcomes.
5. oneM2M release 2 published in ITU
6. Need for effective collaboration of SDOs, considering their working procedures

Suggestions to ITU

- ❑More such timely and substantive workshops like this one!
- ❑Can the limited number of quantum standardization experts from all over the world, e.g., China, Korea, Japan, India, Singapore, US, Canada, Europe, Russia whose experts joined this event, be united under the umbrella of a "Quantum Collaboration"?
- ❑Co-located meetings of ITU/ETSI/SC27…?