# Quantum Communications and standards

**Andrew Lord**
**Senior Manager Optical Research, BT**
**Date: March 2021**

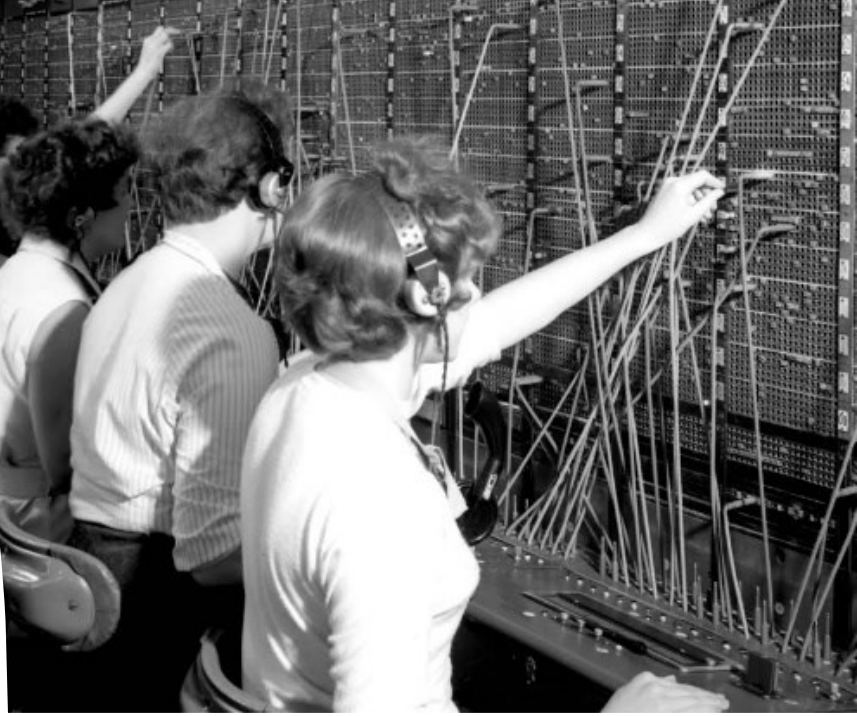
# Optical Networks Research Scope

**19th / 20th Century saw massive world-wide infrastructure projects**
Railways, electricity grids, water supplies, telephone networks

**21st Century is also seeing massive world-wide build**
High bandwidth wireless access
Optical Fibre to billions of homes

**The fibre already installed is a small fraction of what is to come**
World-wide project will take decades
Cost $100s bns
Will have to endure for ~100 years or more

**Optical technology underpins the future**
Essential for all future 5G++ networks
Essential for all consumer internet
Essential for all future smart cities, IoT



**Fibre to homes / 5G cells is a century-scale investment with century-scale impact**

# Quantum technology has unstoppable momentum

**QuantumCTek Sets China Stock Record, Rallying Up to 1,000% on First Trading Day**

DATE: JUL 09 2020 / SOURCE: YICAI

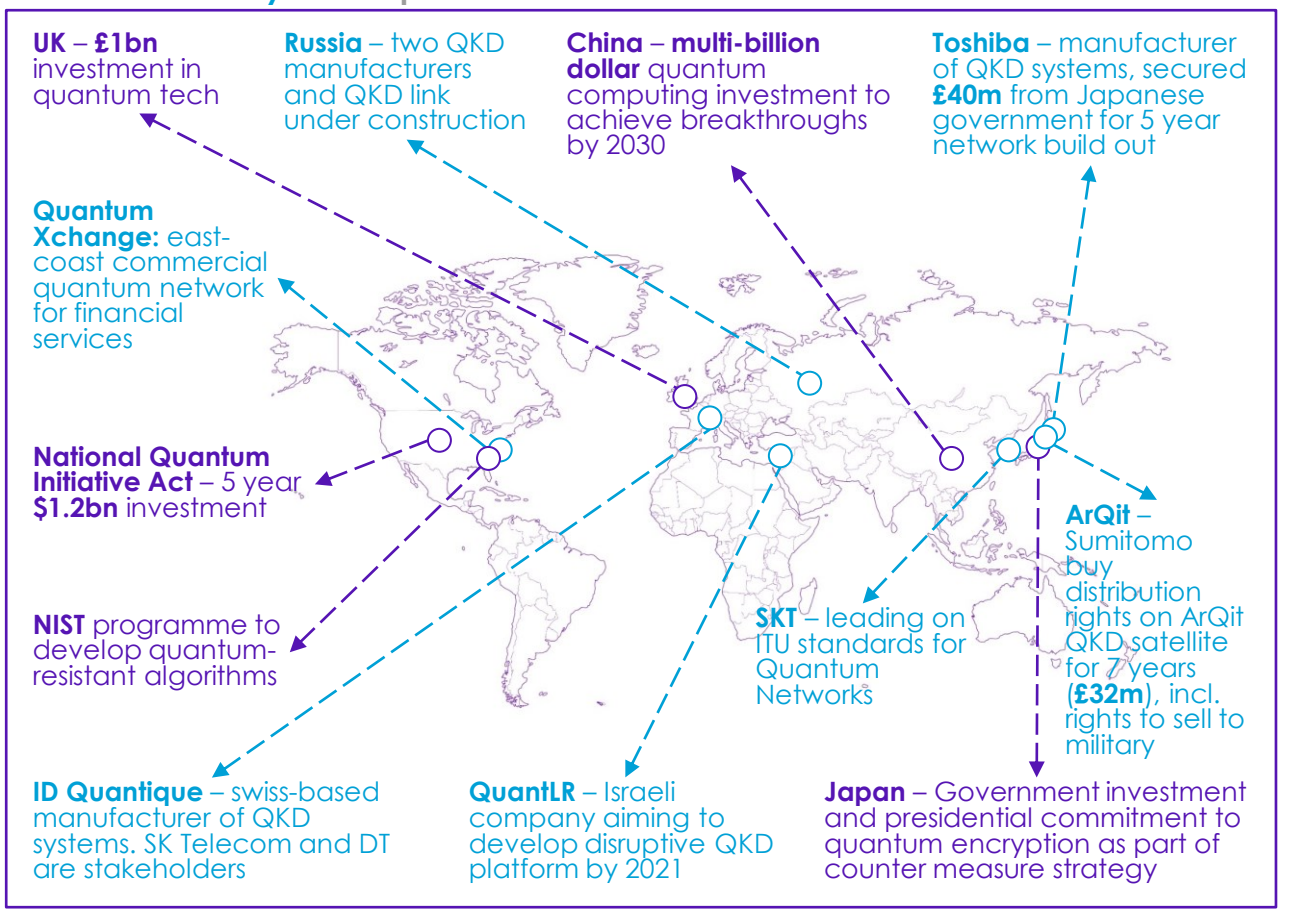
https://www.yicaiglobal.com/news/quantumctek-sets-china-stock-market-record-rallying-10-fold-on-first-trading-day

Quantum Technology is an area of research that is extremely important for BT, due in part to the promise of new breakthroughs in telecommunications and indeed the wider scientific field. The technological opportunities are diverse and developing quickly.

## Quantum technology areas

| | |
|---|---|
| **Quantum Clocks & Timing** | Orders of magnitude more accurate than atomic clocks, with a wide range of prospective applications across sectors including finance, transport, telecommunications and energy with implications for critical national infrastructure. |
| **Quantum Imaging** | Quantum imaging systems build a picture of the environment, including 3D, with obvious military and law enforcement applications, driverless cars, search and rescue, infrastructure monitoring and maintenance. |
| **Quantum Sensing & Measurement** | Quantum sensors have higher sensitivity, accuracy and speed, resulting in sensitive magnetic field and gravity sensing giving rise to potential applications in resources, manufacturing, health and telecommunications. |
| **Quantum Computing & Simulation** | Advanced problem solvers and modellers that can tackle and analyse problems inaccessible by conventional computers, with applications for BT and customers with high volumes of data and parameters – e.g. network planning, field force planning, resource optimisation, simulation, etc. |
| **Quantum Communications** | Cryptography underpins the security of our financial, business, government and personal communications. Some forms of encryption in use today are vulnerable to attack by future quantum computers. Quantum Key Distribution is the only provably secure option today, leading to opportunities for providing ultra-secure network communications. |

## State and Industry developments




## Illustrative markets and impacts

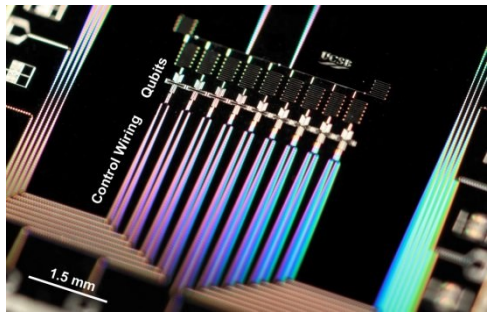
**Oil & Gas**
Gravity surveys with quantum sensors could aid discovery of oil and gas resources, and increase yields – potentially worth trillions.

**Environment**
Quantum sensors for measuring gravity could aid flood prevention by allowing us to monitor the water table more accurately.

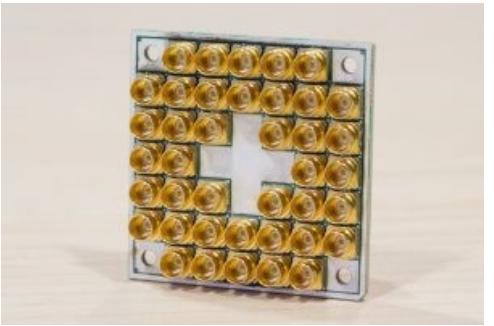
**Data Security**
Increase data security on networks, reduce theft of sensitive information and promote trust in network-based products and services.

**Defence & Aerospace**
Highly dependent on precise navigation, timing and sensing, all of which will be improved by quantum technologies.

# “Q-Day”



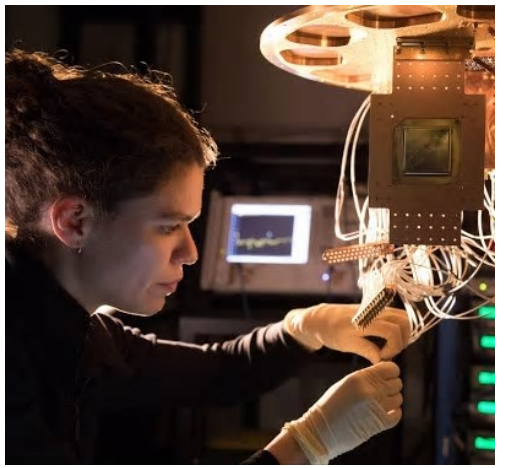

Google: 9 qubit trapped ion device, 2016



Intel: 17 superconducting qubit chip, 2017

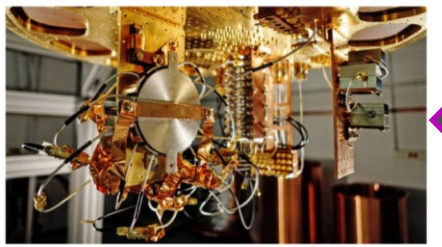
IBM: 50 qubit trapped ion machine, 2017

Google: 72 qubit ‘Bristlecone’, 2018



China: $11bn quantum computing investment

?



Sep 21st 2019

ScienceNews

ALL TOPICS LIFE HUMANS

NEWS QUANTUM PHYSICS

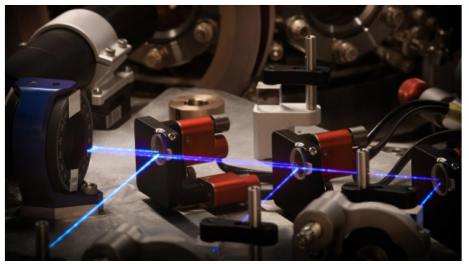
Rumors hint that Google has accomplished quantum supremacy

Reports suggest a quantum computer has surpassed standard computers on a specific type of calculation

MIT Technology Review

Computing Mar 03

Industrial giant Honeywell says it’s built the world’s best quantum computer



The news: Honeywell, a US company best known for its home thermostats, has

March-June 2020

# BT's interest in Quantum Communications

**BT has spent several years integrating QKD with mainstream transmission for full-service quantum encryption. We have a lot of experience in doing this now**

**We have spent a lot of time working with potential customers – educating / understanding requirements**

Customer curiosity around quantum has exploded over the past 12 months coupled to QC progress

**We have built a range of demonstrators and trials:**

Integrated QKD + classical WDM with Toshiba and Adva
Quantum Comms Hub QKD system between Adastral Park and Cambridge – IDQ + Adva
Customer QKD trial with National Composite Centre in Bristol – with Toshiba and Adva – over Openreach commercial fibre product
A range of lab demos

**We have more recently been building internal business cases / propositions for a QKD service**

Still a Work in Progress
What will be the impact of NIST-approved mathematical solutions in ~ 2 years?

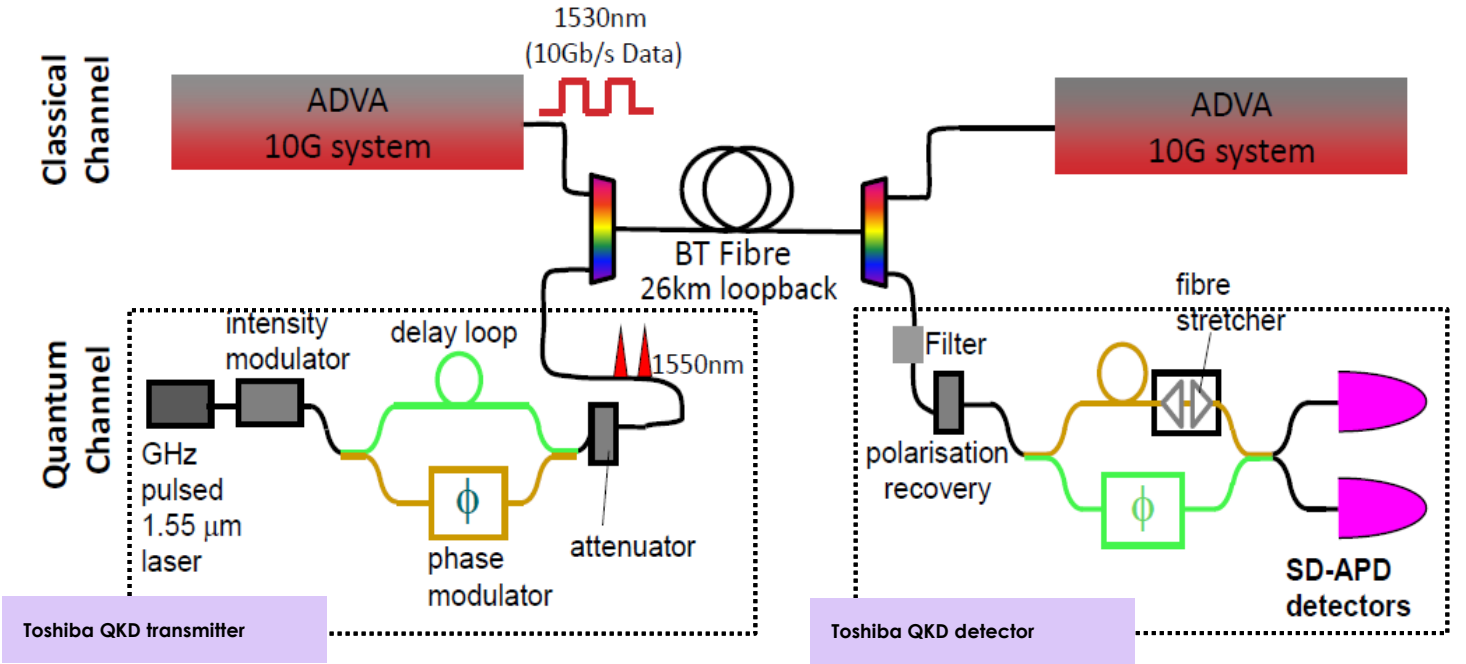
**Deep interest in Sat QKD**

**Additionally – close relationship with Toshiba on terrestrial QKD**

**Other activities include ongoing Penetration Testing / Assurance, Standardisation, Key Management, Overall system integration ( Ethernet etc)**

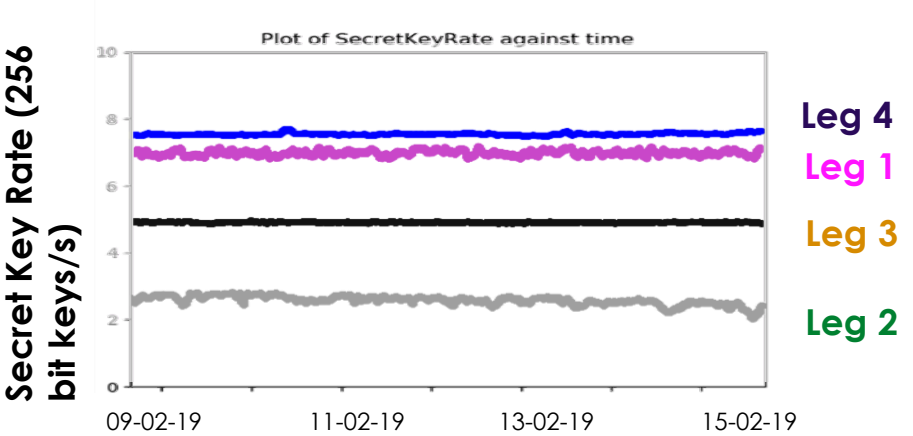
# World first real time QKD + 10Gb/s field trial using commercial hardware (2014)

## Adastral Park – Ipswich (27km)



# UK's ultra-secure Quantum Network link between Research and Industry


- Commerical ID-Quantique QKD equipment
- Commercial Adva DWDM – 5 x 100Gb/s
- Full installation over installed BT fibre and in BT exchanges




Real world QKD experience on this link for well over two years
Connections into a wider QKD network to Bristol being built

Recent data showing the fluctuations in Secret Key Rate over each link for a week

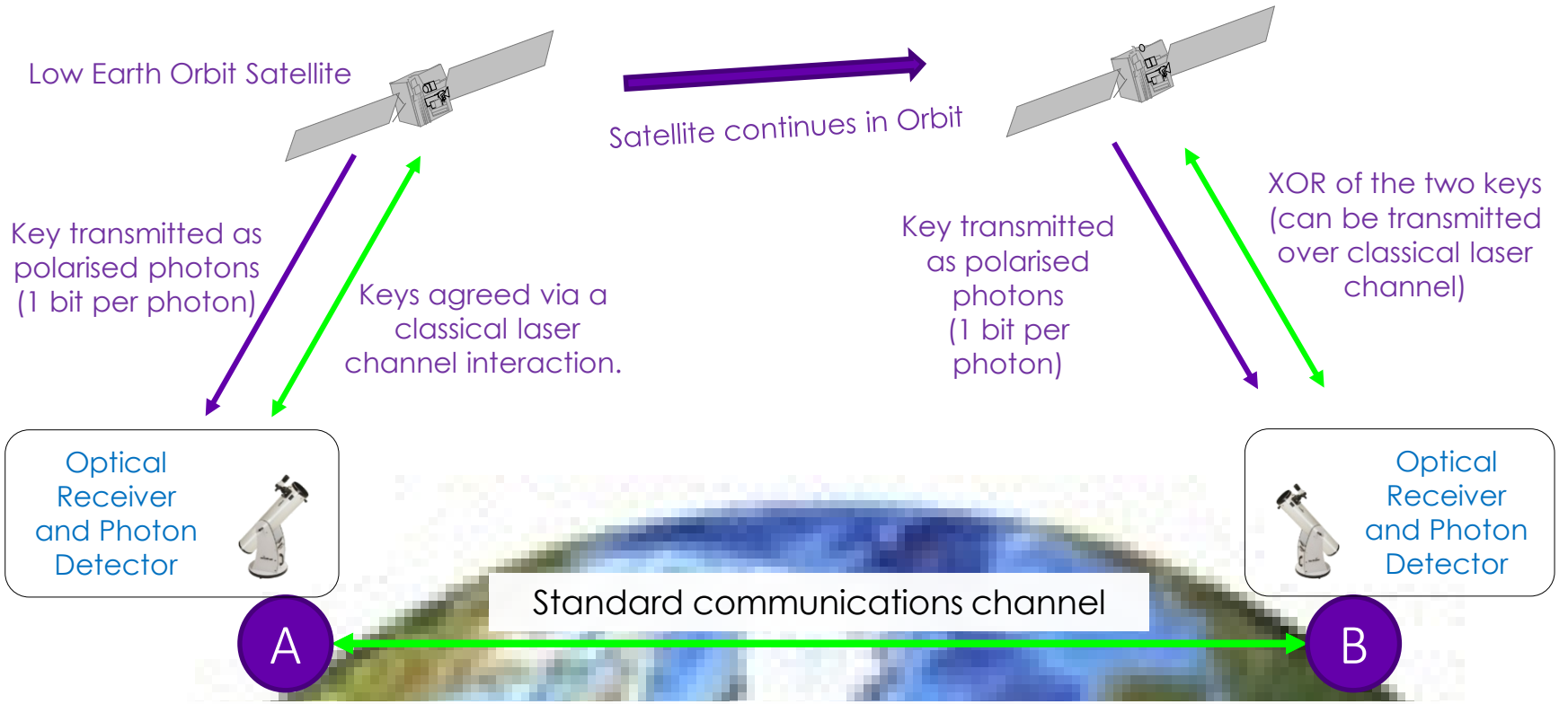
UNIVERSITY OF CAMBRIDGE · BT · IDQ · ADVA Optical Networking · QUANTUM COMMUNICATIONS HUB · EPSRC · BT

# Satellite QKD

Satellite QKD networks moving to commercial reality in next 2 years.

1 Satellite transmits key material to location A via the optical network.

2 Satellite transmits key material to B, along with the XOR of both keys.




4 B decodes the message with own key and the XOR'ed keys.

3 A encodes a message with the key received and sends the cipher text to B via a classical "open" terrestrial channel.

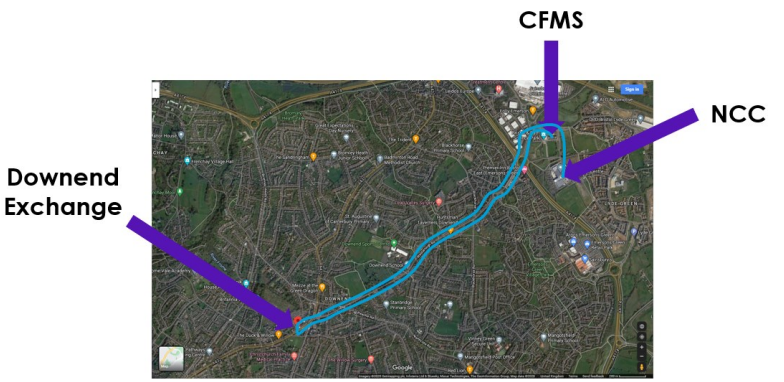
# First commercial trial of QKD and Industry 4.0

NCC – National Composite Centre based in Bristol
https://www.nccuk.com/

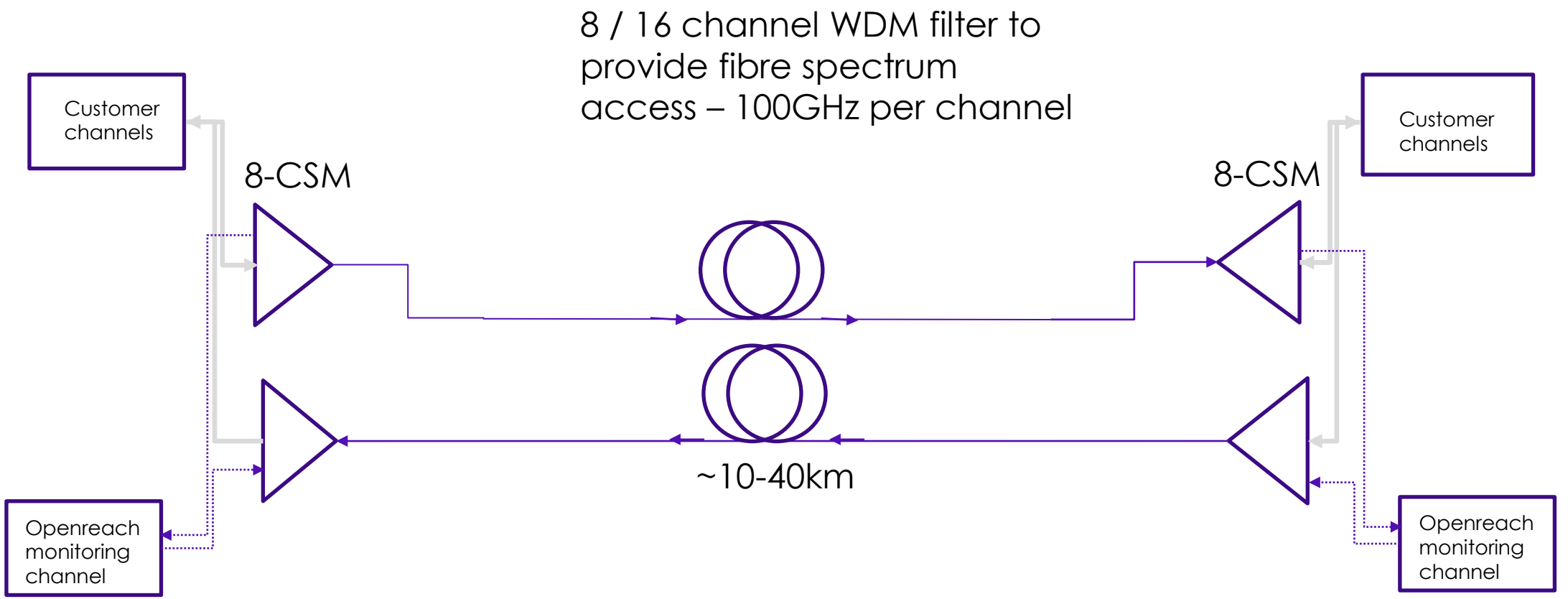
How to design a QKD-secured data link between two NCC buildings

Using all commercially available products, including the fibre access

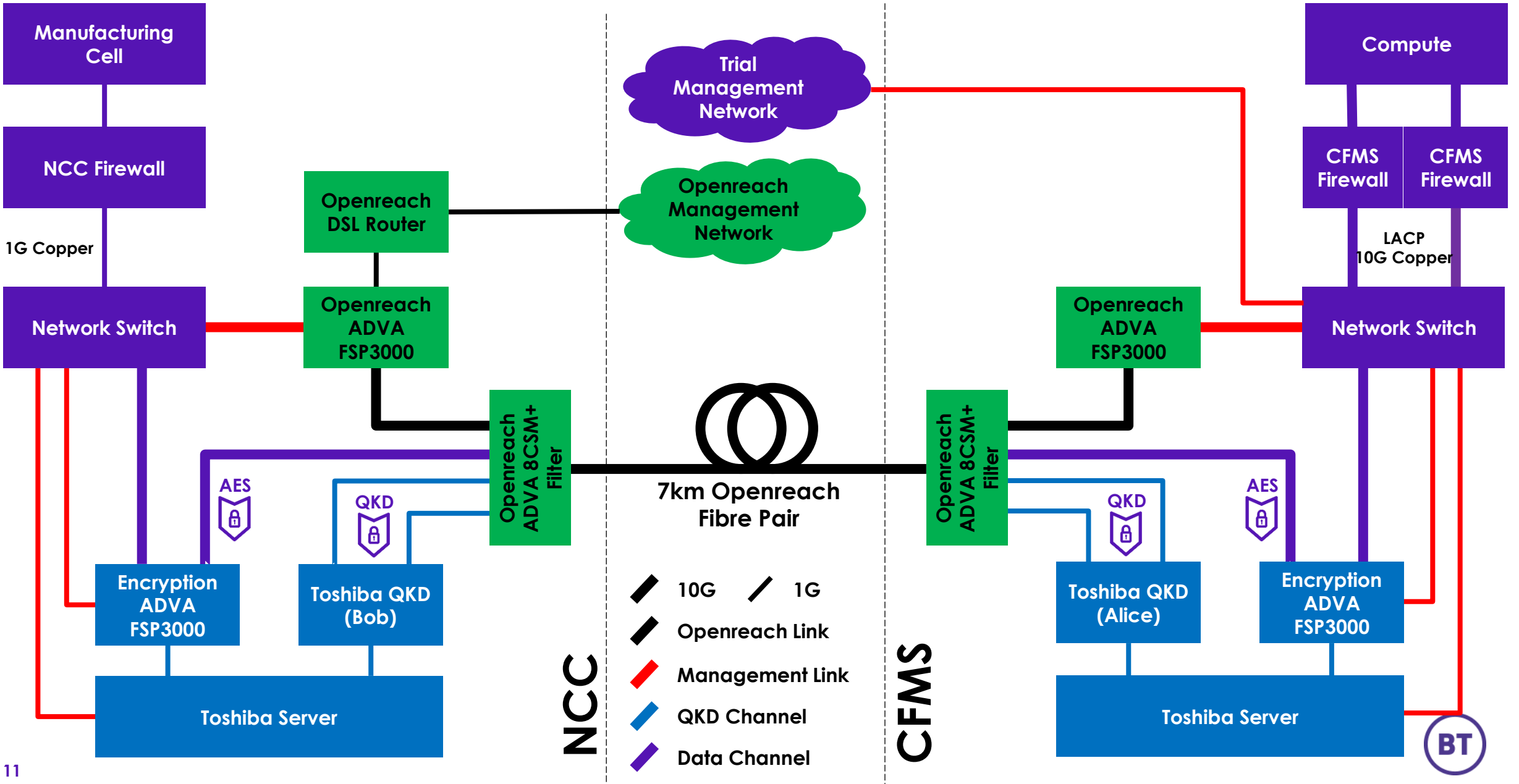
- Toshiba QKD solution – carefully designed for working alongside classical channels
- Adva ethernet transmission solution – 10GE with external key input feature
- Openreach OSA filter connect fibre product – provides managed access to 8 / 16 channels of optical spectrum

# Interfacing QKD with a standard Open Reach fibre product – Optical Filter Connect



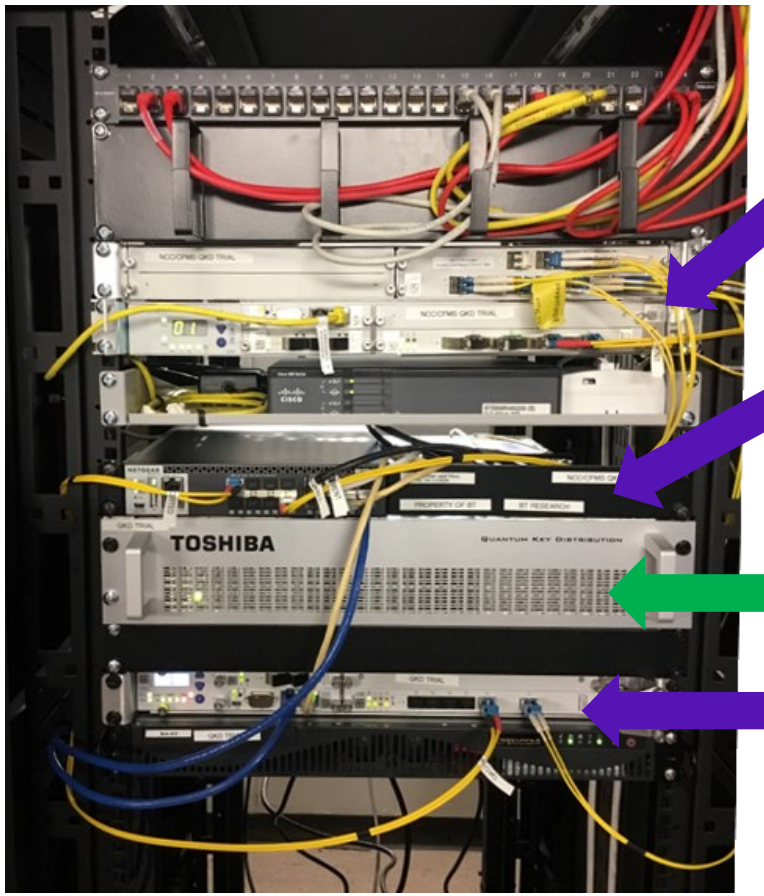
# End to End Architecture



# The NCC and CFMS PoC Trial

## Equipment as Racked

### NCC



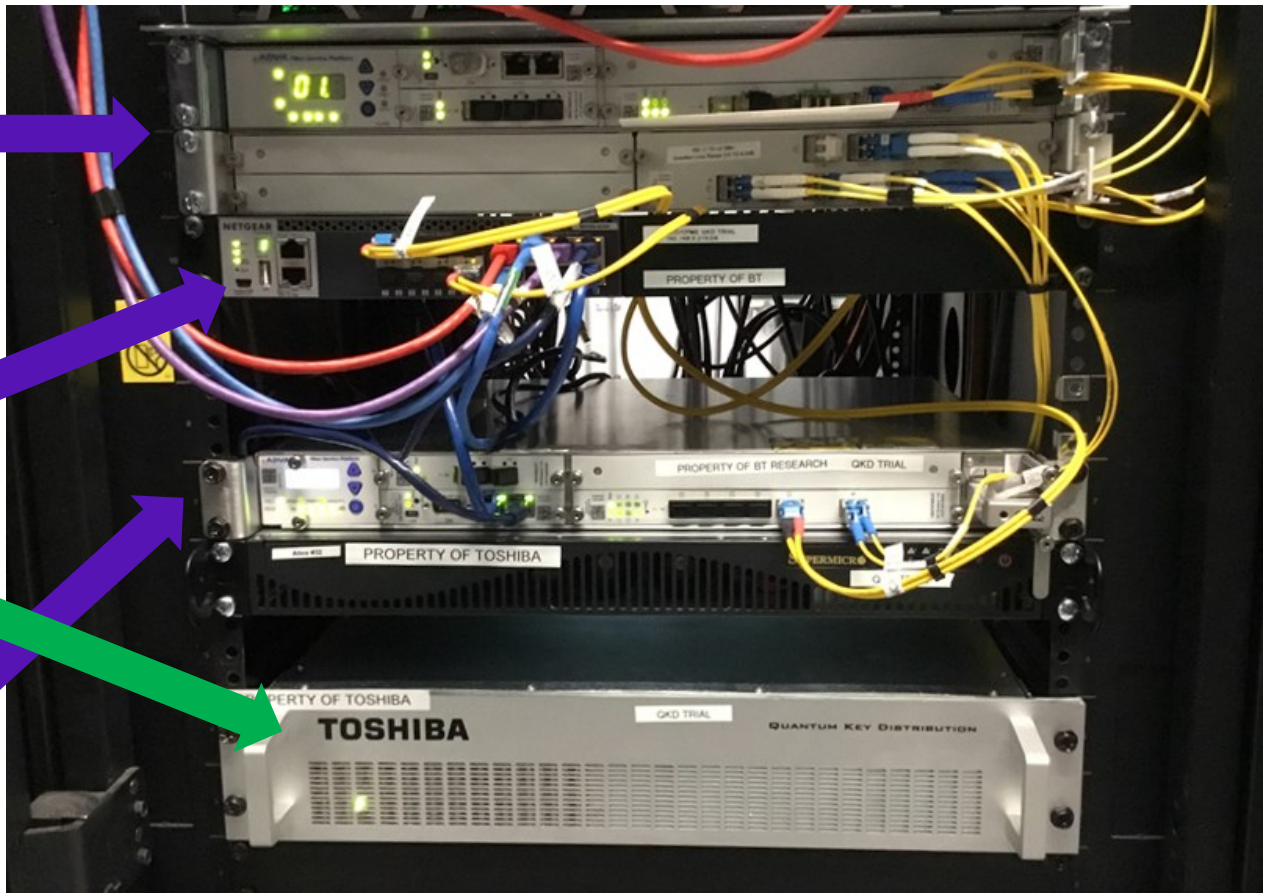

Openreach OFC

Network Switch

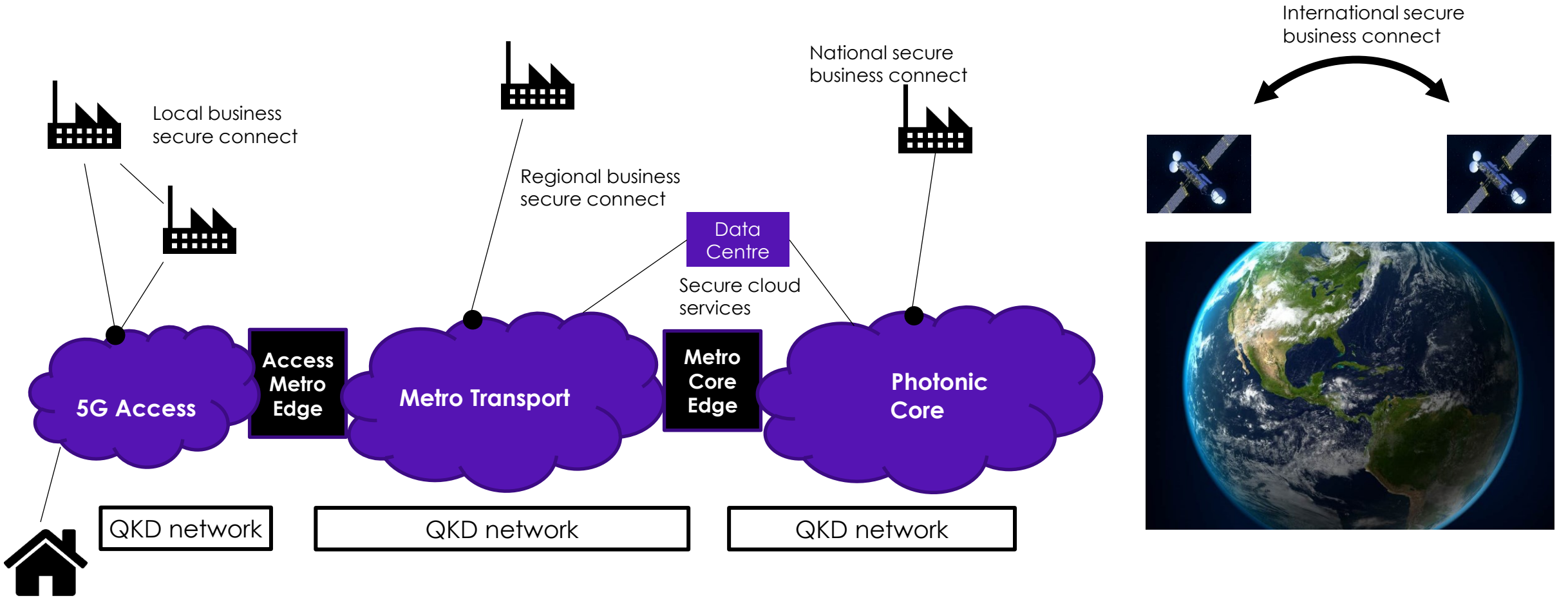
QKD

Encryptor

### CFMS



# Where will customers want to see QKD in their networks?




- Secure connections between business sites (could be local, regional, national or international)
- Secure back-up to the cloud / DC
- Beyond the access network, connections share fibres
- Metro and Core networks comprise fibres with multiple wavelengths
- IP routers usually used for packet layer traffic networking

# Independent national key distribution network – towards the Quantum Internet

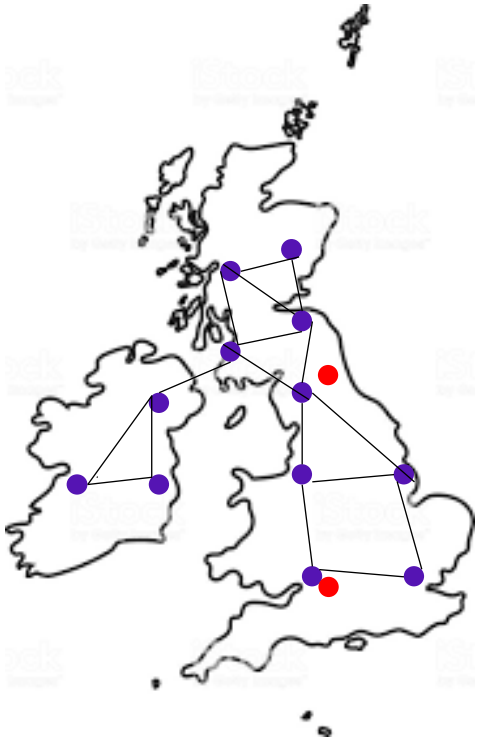
Sat QKD stations

It may be that QKD isn't optimal when slotted in over optical transport networks

Ultimately a separate QKD network, designed to be optimal for QKD, on separate dark fibres, will be more cost effective, have higher key rates and be more robust

But this is a significant undertaking

So we need the early bespoke experience before embarking on something of this scale

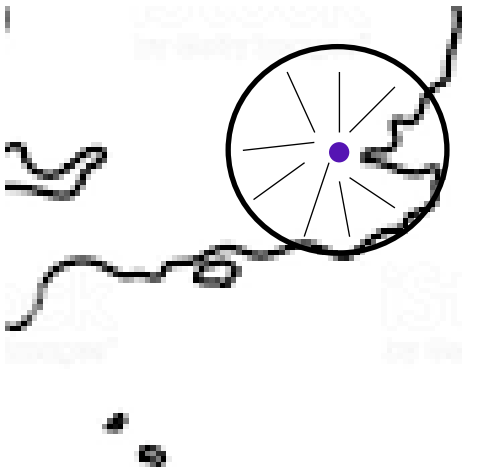


## QKD 'Core'

Minimise QKD trusted nodes / maximise distance between them

Co-locate with major cities where possible

Resilient routes where possible



## QKD 'Metro'

What architecture? Star / ring etc?

Different technology? E.g. cheaper QKD / integrated photonics?

# Standards in quantum – where and when are they needed?

**Quantum in in a highly innovative phase – differentiation leads to huge benefits**.

Standardising everything TOO EARLY would be a mistake
How would we know WHAT to standardise?
We might inadvertently rule out a transformational technology
Multiple standards compete to standardise too early and I doubt quantum is ready in general for this

**Interoperability can be both good and bad**

Direct OPTICAL interop is VERY hard even for classical systems ( starting to see 'standards' – e.g. OPENROADM – but usually applied to less challenging networks)
Component level standardisation should be ' proceed with caution' – e.g. single photon transmitters are still in a deep innovation cycle
But common INTERFACES potentially help everyone – e.g. helps start-ups with novel devices

**Areas where standards could help**

Improved optical filters with high out-of-band isolation
Improved attenuation / reflection characteristics for all components ( dBs are precious!)
Interfaces for components, sub-systems, QKD boxes ( e.g. QRNG) – standardised quantum APIs
Assurance, accreditation etc

BT

# Conclusions

**QKD making a great deal of progress**

**Industrialisation of QKD is an active topic with fully commercial solutions now available**

**But QKD is only one part of the ultimate solution**

**Next steps are about extension from pt-pt through to network capability**

**But there is stiff competition from PQC**

**Network operators may need to take a lead – using QKD to secure the underlying infrastructure**

**Roadmap through to a quantum internet is a very long one**

**Meanwhile – there are customers requiring ultimate security which provides QKD with a niche foothold.**

**BT as the national purveyor of trust**