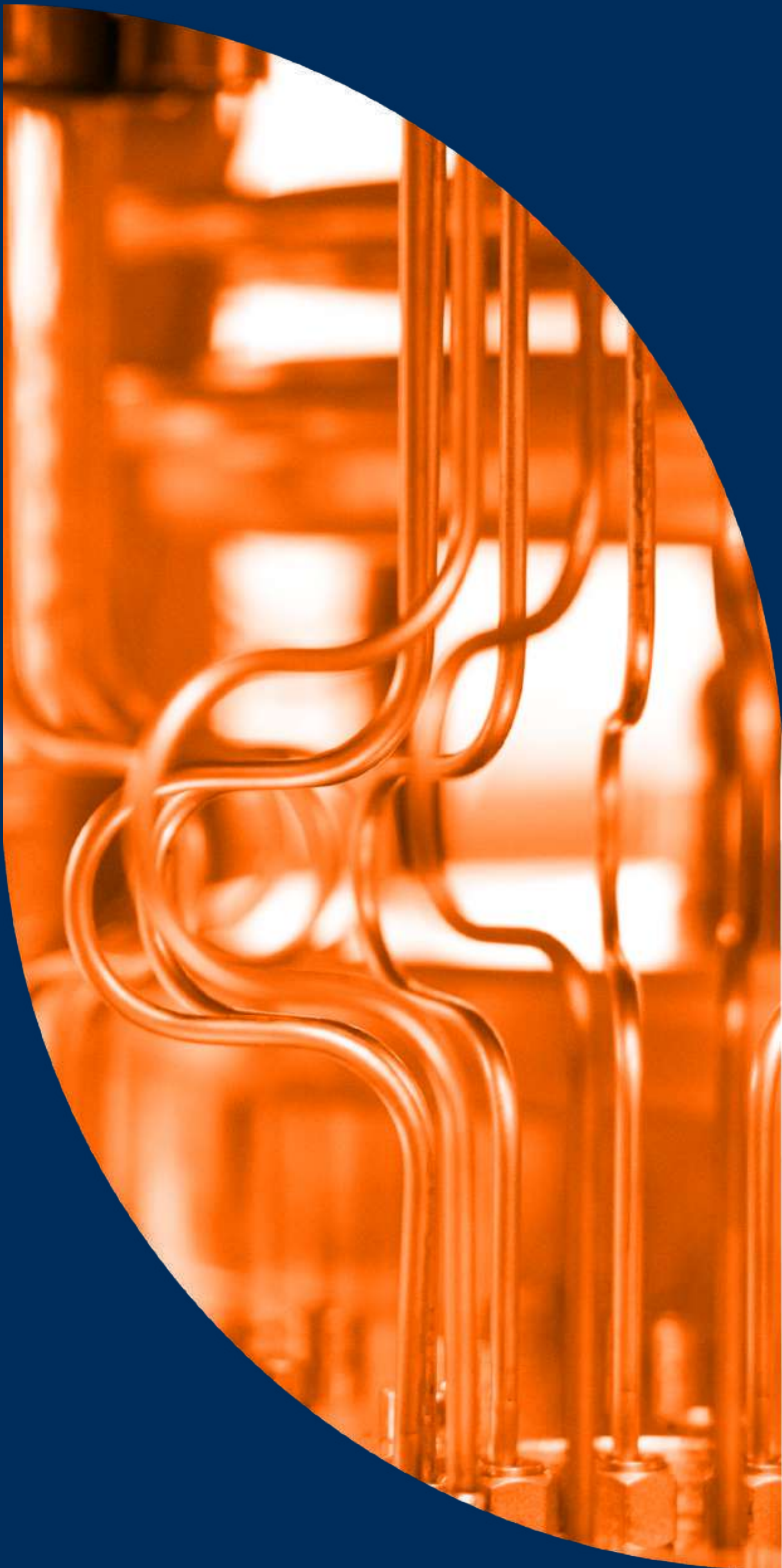

Mapping the Supply Chains for Quantum Communication

Towards European technology sovereignty in an emerging industry

Quantum Delta Nederland

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Content

Mapping the Supply Chains for Quantum Communication

1 Introduction

This is the second white paper published by Quantum Delta NL on quantum technology supply chains. In September 2022 we launched the first assessment on quantum computing supply chains[1]. This assessment turned out to be highly useful to guide discussions about open strategic sovereignty in an emerging technology field. Later that year, we decided to follow-up with a second study on quantum communications technology.

Quantum technology is still in its early days, but the contours of an emergent industry are being shaped today. As one of Europe's leading quantum ecosystems, Quantum Delta NL believes that we have a responsibility to think ahead: how will and should a quantum industry look like and how can we anticipate its impact on the economy, society and global technology landscape? Quantum communications is a case in point.

Multiple quantum communication types are currently being developed side-by-side, each with specific advantages and disadvantages, with each a different supply chain. There is also an ongoing debate about post-quantum encryption and Quantum Key Distribution (QKD), both part and parcel of what promises to become the future internet infrastructure. As we see the quantum ecosystem grow at a rapid pace, we need to think about preventing supply chain disruptions as we have seen happening for example with Covid-19. This line of thinking serves the goal of the European Union (EU) to increase technology resilience and to work on 'open strategic autonomy'.

As a national technology programme, we are working with partners world-wide. Quantum is a global effort with connections that transcend nation state boundaries across the globe. At the same time, we believe that quantum is part of a truly European deep-tech agenda. To ensure that we create a solid foundation for this emerging industry, we are proactively investing in a dialogue with relevant players from science, industry and policy about the role of quantum in strengthening European sovereignty.

Quantum Delta NL took the initiative to map the existing supply chains for quantum communication hardware, in close collaboration with the Dutch national research institute TNO. The result is a supply chain canvas methodology for quantum technology, adopted from the original study on computing. It provides a comprehensive overview of the various components for some of the leading hardware platforms for quantum communication. We created a canvas that allows to incorporate multiple types of quantum communication networks as well as variations within a type. This allows us to create a similar graph as our computing study that allows to identify bottlenecks, and core strengths and weaknesses

In turn we plotted the results of the assessment on our visualisation tool (developed originally for quantum computing) to help guide discussions about potential bottlenecks and strategic investments.

[1] Mapping Quantum Supply Chains (2022), Quantum Delta NL, TNO

Since we started this work, we received a lot of interest in the methodology we developed. There is a wide recognition that the type of insights gained are highly relevant for the future of deep tech in Europe.

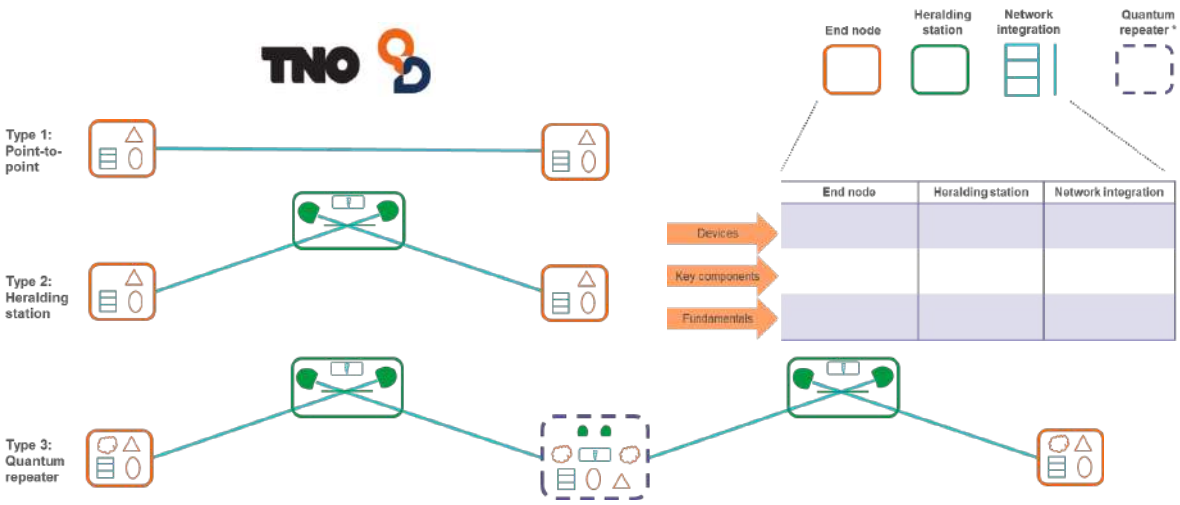
This Quantum Delta NL White Paper serves as a quick manual to our supply chain assessment; in the following you will find the methodology and a summary of the first results for quantum communication.

2 Methodology

Here we use the same methodology that we developed for mapping quantum computing supply chains that consists of three steps: 1) canvas design, 2) filling the canvas and 3) validation. We found that the biggest challenge was to (re)design a suitable canvas for the quantum communication domain. This is due to the fact that there are many different compositions, for example based on functionality[2], standardisation roadmaps[3], or a quantum network stack[4]. Since we are focusing on the supply chain, for this study we chose to subdivide quantum networks based on hardware elements, as shown in the figure below.

Additionally, each network type can be used for multiple different application protocols (e.g. measurement-device-independent QKD or twin-field QKD for heralding stations) and they can be based on multiple underlying physical platforms (e.g. nitrogen vacancy centres or trapped ions for quantum repeaters). These variants can all be captured using our canvas methodology.

In total we performed nine interviews to map the canvas for all three network types and we considered at least one variant per network type.



Supply chain canvas for quantum communication, for which we used a system breakdown structure for quantum networks based on hardware elements. *We assume that in terms of components, a quantum repeater generally consists of hardware elements that are also present in the end nodes and heralding stations.

[2] Quantum internet: A vision for the road ahead | Science
[3] [2203.01622v4] Towards European Standards for Quantum Technologies (arxiv.org)
[4] A Link Layer Protocol for Quantum Networks (arxiv.org)

3 Results

We combined the results of all three network types in a single figure, building on the visuals developed for the quantum computing study. The horizontal axis represents the concentration of supply (the number of suppliers), and the vertical axis represents the so-called EU-substitutability (potential for EU suppliers to offer the same product).

In short: the concentration on the horizontal axis indicates the number of suppliers and their market share. If a small number of suppliers have a high market share, concentration of supply is high. The EU-substitutability on the vertical axis gives an indication of the potential to substitute a component, where a high substitutability implies that there is (a potential) capacity in the EU to produce a substitutive component. This matrix subdivides into four quadrants, which we also used in our previous study on quantum computing supply chains.

When looking at the four quadrants of this matrix, we can give each a 'title', which reflects its specific characteristics. Each quadrant allows for a different interpretation in view of strategic dependencies and possible responses / (policy) implications:

- **Monitor:** sufficient alternatives exist within and outside the EU.
  Response: monitor the situation and try to consolidate.

- **Increase:** there are few suppliers of the component, although they are already based in (or can be replaced with an alternative supplier within) the EU.
  Response: stimulate an increase in suppliers within the EU.

- **Investigate:** there are plenty suppliers, but they all reside outside of the EU.
  Response: investigate how to deal with the situation, e.g. by strategic investments to create an EU ecosystem.

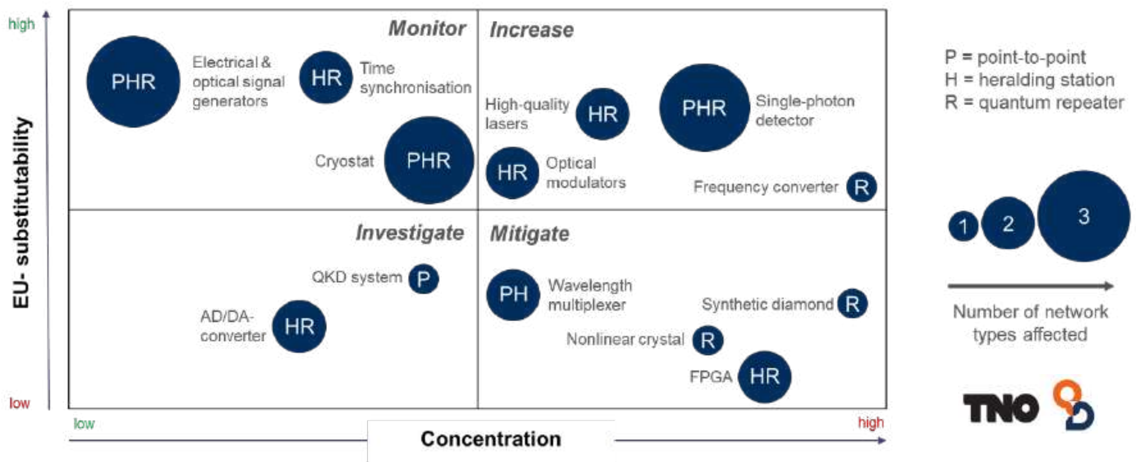
- **Mitigate**: few suppliers exist and there is little potential for finding a substitution within the EU.
  Response: mitigate this strategic risk, e.g. by pursuing alternative technical solutions.

Even though these results represent only a fraction of what is currently available across the EU, we can already derive several valuable insights from this exercise.

The result is displayed in the figure below. Note that the components are placed based on first-hand vendor information, without taking the underlying supply chains for sub-components into account.

In general, we can see that most components related to point-to-point networks (P) have a relatively low concentration of suppliers, while those related to quantum repeater networks (R) have a high concentration. This can be explained by the fact that point-to-point networks has relatively high market maturity, while commercial quantum repeaters do not yet exist.

Even though the technology is still under development and supply chains are far from established, this methodology produces relevant insights even for today: for example, we find that field-programmable gate arrays (FPGAs) present a clear bottleneck again – a finding that came out of the study on quantum computing as well. The market is dominated by only a few non-EU players, which are moreover affected by the current semiconductor supply chain shortages and can therefore have very long lead times. On the other hand, the EU has a relatively strong market for high-quality optical elements, which are in the top-right quadrant.



Result of the supply chain mapping, in which the information from the canvasses of all three network types is combined in a single matrix.

4 Conclusions

We have successfully extended the canvas methodology that we used for quantum computing to map the supply chains for quantum communication networks.
Our methodology allows to capture multiple network types as well as multiple variants per type. The resulting component mapping leads to actionable insights related to the alleviation of bottlenecks and strategic investment opportunities.

A natural extension to this work would be a similar assessment for the quantum sensing domain. Additionally, our results can be strengthened by adding more quantum network types and/or variants. One could also include an assessment of the required critical raw materials or intangible assets such as patents, investments, software, and workforce.

We will cooperate with our European partners to expand upon our work and validate its insights. Please do not hesitate to get in touch with us for feedback, more information, or opportunities to collaborate!

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