

# **Embedded networks**

## Lecture summary for FRUCT seminar in Turku

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The lecture provides an overview of the existing types of embedded networks, the available technologies, their strong and weak sides and the application areas where the available solutions are deployed. We start lecture by giving historical excursion to 6 years back and present the state of art of mobile devices interconnect solutions at that time and deriving with you a motivation for mobile industry to start looking towards embedded networks research. This lecture describes general context, requirements and reasons, which created basement of our research. At the first part of the lecture we also illustrate how new requirements and requests for changes came to the picture, so that it gives a full picture of the progress in embedded networks research for mobile industry up to now, when we have first MIPI UniPro standard proposal. At the same time we make a brief overview of other existing embedded network technologies, e.g. SpaceWire, PCI Express, etc., which were at different stages considered as possible solution for mobile industry.

In the next part of lecture, we give an overview of what types of embedded networks exist and provide comparative analysis of different wired network types, e.g. chip-to-chip, die-to-die and on-chip, as well as comparison to the new area of research – wireless embedded network solutions. In order to better understand special features of embedded networks, we also provide a comparison to other feature-wised close network solutions, e.g. sensor networks.

The main body of the lecture describes our research area, the path that we took and current state. The first step of our group in developing embedded network architecture for mobile devices was evaluation of the available solutions. We have studied a number of the existing solutions and one of the main finding of this study was that many industries with completely different target applications and ecosystems are sharing the same needs and requirements for the embedded network architectures. The lecture provides more information about our key findings and derived conclusions. Among the evaluated solutions, Spacewire was one of the strongest candidates, which fulfills most of our basic needs. However, lack QoS and L4 protocol support and strong orientation on use of DS coding (which is not scalable for xGbit/s PHYs) were the main factors why Nokia has decided to develop new embedded network architecture for mobile devices. Another negative factor was lack of information about further development of Spacewire, as based on the publicly available sources one could conclude that Spacewire specification work is completed and there are no plans for future development of the Spacewire standard.

With this background, approximately five years ago we started development of Nokia proprietary embedded network architecture, which later has been taken as one of the basic proposals for MIPI UniPro standardization work. The lecture gives an overview of our work done in the area, defines the original motivation and requirements in comparison to existing

solutions, set our key high-level targets, as well as positioning our activities in respect of mobile and other industries.

The special attention in this part of the lecture is given to comparison of Networks on Chip (NoC) versus chip-to-chip embedded networks. We explain a motivation for such a split and discuss whether it is artificial classification or there are some fundamental differences from the architectural point of view. What are the key commonalities of these network types and what are the differences in requirements and use cases expectation. The discussion is also covering such important issues as underlying PHY solutions, the expected speed of interconnect links and network elements, traffic latency expectations and cost requirements of the total cost of solution. As a consequence what implications all these factors have to the network topology and routing architecture and techniques. The key question here is to understand whether there is a unique way to handle both technologies at the same time. If we can come up with such solution it would lead to creation of uniform universal solution for embedded wired networks. For that we need to analyze what technical points are common, e.g. requirements for reliability, QoS, security, power management and so on.

Another key aspect of our study was management of embedded networks. Here we would like to share the key learnings from our study and give an overview of the whole path of the management solution development starting from a base idea and vision and up to fully ready proposal for industrial standardization in MIPI.

The special emphasis of the lecture will be on future directions of our research. We are going to list a number of open issues in the area and propose a number of open research topics for FRUCT students. In the context of a generic embedded network solution applicable to on-chip, die-to-die and chip-to-chip, reliability, QoS, security and power consumption management are crucial topic to harmonize between the different domains. Also of great importance is the identification of particular technical aspects very beneficial in a certain domain: when identified, a layered or abstracted architecture should be defined to be able to take advantage of the solution. In particular, topics related to topologies, redundancy, routing, broadcasting/multicasting, etc. are becoming important even for standardization. If you are interested to make FRUCT research project around one of the listed above topics or you have your own research question on the related topic, you are welcome to contact us.

In the conclusion of the talk we summarize the path that one needs to take for moving his/her research ideas and visions to the industrial standard. We hope this summary will help young specialist to better understand possible ways how they can push their brilliant ideas to the industry. We also summarize the key points around why research in the area of embedded networks is an important and very interesting topic for the young specialists in different domains. According to our vision this field will stay “hot” still for a while and now is the right time to join these activities.