PROF. DR. CLAUDIA LINNHOFF-POPIEN
Prof. Dr. Claudia Linnhoff-Popien holds the chair „Mobile and Distributed Systems“ at the Ludwig-Maximilians-Universität in Munich. She finished her Ph.D. thesis at the Technical University Aachen and gave lectures at the University GH Essen. She did postdoctoral research at the Washington University of St. Louis, Missouri, USA before she was appointed to a professorship at the LMU Munich in 1998. She is board member of the Institute for Informatics, member of the „Münchner Kreis“ and co-founder of the ALOQA GmbH. The latter had one million registered users when it was sold to Motorola Mobility in 2010 marking one of the biggest exits in the history of start-ups of German universities. Further, she is head of the lead project „Innovationszentrum Mobiles Internet“ of the Zentrum Digitalisierung. Bayern (ZD.B) funded by the state of Bavaria. She is also scientific advisor of the VIRALITY GmbH and chair of Digitale Stadt München e.V.

Quantum Computing – a new hype?

Quantum Computing is a key technology of the 21st century. Currently we are in the middle of the second quantum revolution. Nearly a century ago Albert Einstein, Nils Bohr, Werner Heisenberg, and many others laid the foundations of quantum physics. Any attempt by a computer scientist to understand these physics will most probably fail. This technology is now in the process of entering the world of computers. The opinions about quantum computing today range from “not even started” to “totally successful”.

Do you work for a company which plays along with every hype? Which always strives to be at the forefront of innovation? To be considered as being innovative, to be one step ahead of the competition, to recognize disruptive technologies which are created to generate platform business as much as possible in order to lay the foundation for the future? Many of these “seedlings”, established with vast resources and much euphoria, have grown into large enterprises, especially in the area of digitalization.

Often, however, such a vision is only hype. Many technologies are just too complex, require too much intervention in the infrastructure, or are just not readily accepted by the market. Blockchain is a prime example. Many business units have been created around consultation and implementation of Blockchain technology. Yet this technology is so storage-consuming and computing-intensive that it is suited mainly for the finance sector. Even the Bitcoin-US-Dollar rate climbed to almost 20,000 dollars by the end of 2017, only to crash below 4,000 dollars just over a year later.

What, however, is the situation with Quantum Computing?
This completely new technology has been rapidly gaining visibility in the last few years. While the basis of quantum mechanics spent almost 100 years being of more theoretical than practical relevance, now that they enable new applications in IT, the time has come when more or less all companies are diving into it.

Let us begin with the foundation – the hardware. Numerous companies claim to build quantum computers and to offer the technology in widely varying architectures. IBM already offers its customers the first solutions in form of a Quantum Gate Model, which is still very limited in storage and computing capacity. Moderate performance capacities are freely accessible and the IBM Q Hub provides an interface for the application of this computer model and is being made available to large enterprises. The providers Google and Microsoft are testing comparable computers whose utilization has so far been restricted to laboratories. The Canadian company D-Wave achieved a breakthrough in the maturity of quantum technology during the last few years with a Quantum Annealer This implementation of so-called adiabatic computing is suitable for a first practical utilization. Fujitsu is exploring the possibility of a practical use of the technology, but is relying on classical hardware elements in which not the technical novelty, but rather the embedding in a larger service package plays the crucial role.

The prices for this technology move in rather large circles – this is understandable because Research and Development are a high cost factor when you consider the extremely low number of units of the machines sold. For access to an IBM Q Hub a contract at a six-figure price can be negotiated and you pay a low eight-figure price

for a Quantum Annealer, or rent it as a cloud-service with a fixed quota of computing capacity. In this case, you are talking about a four-figure sum for several months of participation. So, dare to tackle the adventure, find the right concept according to your requirements and test it for your company.

This brings us to the real problem – how to implement. This consists of two phases.
For a start, you need an expert inside or outside of the company, with whom you can collaborate, who shows you the possible areas quantum technology can be used for in your enterprise. Make yourself familiar with, and identify areas in which quantum technology can be used to solve optimization problems. Look at examples from other industries and learn from success stories! Adapt the highly complex and difficult to scale mathematical problems to the specific conceptual formulations of your environment and determine where you can achieve this "wow-effect", when you can see where you can solve the problem with quantum technology.

Begin with the absolute classics – with the travelling salesman problem, in which a salesperson has to travel to, for example, five locations by choosing the optimal route to deliver the products. This optimization problem is the basis of programming an industrial robot, which has to, for example, place five welding spots in the optimal sequence, and, at the same time, cover the least distance. Consider the rucksack problem, or the graph-coloring problem. In live situations, these task definitions can then be used for the gate allocation problem in which the gates at an airport are assigned optimally to airplanes, or to portfolio optimization in the financial sector, or the optimal placement of commercials in the breaks of a TV program. These are all apparently small modules, which are integrated into the large unit. However, they require huge amounts of computing time, if they are not practically insolvable for a sufficient number of cities, points, gates, shares, and advertising clips. Start with these kinds of modules! Look for applications in your everyday business situations, for which you can identify suitable optimization issues. Reserve a small budget and look at applications and solutions, you carry very little risk in this case.

It takes more courage, however, to tackle a major project. In mid-2018, I ran across a press release by Microsoft and DEWA. DEWA (Dubai Electricity and Water Authority) is a company, which is comparable to our domestic public utilities, as it supplies Dubai with grids and infrastructure. This press release stated that the city of Dubai was to be supplied with quantum-based solutions in order to optimize the infrastructure. In the context of a presentation at an international quantum congress in Abu Dhabi, I took a detour to Dubai and talked to a colleague. This is a genuinely big project! With the help of international experts, the attempt was made to solve it. There are no results yet, but the large goal produces large ambitions.

This is the future! Trained experts of tomorrow are required! It is foreseeable that a huge demand will exist within a few years. In our title story "In five years the future will arrive", Bo Ewald states that the technology is very close to breakthrough. University graduates in five years are the beginners of today. We therefore have to act today, and that is why we are doing it! During the summer semester of 2018, I started to include Quantum Computing in the traditional lectures on "Computer Architecture". 500 – 700 computer science students of the LMU Munich not only learn the traditional von Neumann model every year, but also get the chance to program a D-Wave Quantum Annealer.

They do not work on a simulator or a "quantum-inspired" computer, but on a genuine Quantum Annealer. They learn to write down an Ising formula and to fill out a QUBO matrix, that is, to "feed" the computer.

So, what will our world look like in five years?
Quantum computers today are not yet capable of being used in a highly scalable manner for optimization problems. However, they have something in common with traditional computing technology there – hardware is doubling continuously, we can observe exponential growth, even if it is at an early stage. That is why there is reason for hope that soon a valuable technology will be available on the market. This would be especially suitable for optimization issues. There will be traditional computers as well as quantum computers in a universal infrastructure, in case of optimization, the quantum computer will be of great advantage. Problems which so far have been practically unsolvable will be able to be solved in a manageable timeframe.

What does this mean for your enterprise?
Now is the time to be occupied with quantum computing. Learn to understand problem situations from the viewpoint of quantum computing, and to recognize when a computer of this kind will be an advantage. Observe which problem situations exist within your organization, which would be suitable for quantum computing. Start early in bringing a small problem onto a computer of this kind, or to several computer families. Grow with quantum technology, and, in case you do not have the capacity, find a partner who will accompany you on this exciting journey as early as possible.

For more information on this subject, please feel free to visit our QAR-Lab, see:
http://www.mobile.ifi.lmu.de/qar-lab/. We are looking forward to your visit!