

Edited by

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# Shaping Future 6G Networks

Needs, Impacts, and Technologies



# 6G

  
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# Shaping Future 6G Networks

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For 30 years Prof. Magedanz has been a globally recognized ICT expert, working in the convergence field of telecommunications, Internet and information technologies understanding both the technology domains and the international market demands. He often acts as an independent technology consultant for international ICT companies. In the course of his applied research and development activities he created many internationally recognized prototype implementations of global telecommunications standards that provide the foundations for the efficient development of various open technology testbeds around the globe. His interest is in software-based 5G networks for different verticals, with a strong focus on public and non-public campus networks. The Fraunhofer 5G Playground ([www.5G-Playground.org](http://www.5G-Playground.org)) represents, in this regard, the world's most advanced Open 5G testbed which is based on the Open5GCore software toolkit ([www.open5Gcore.org](http://www.open5Gcore.org)), representing the first reference implementation of the 3GPP 5G standalone architecture, which is currently also used by many customers for testing against different RAN equipment in different use cases. For three years, he has actively supported the buildup of emerging 5G campus networks based on the Open5GCore considering emerging campus networks as the prime spot for 5G innovation.

His current research is targeting the 5G evolution to 6G, including Core-RAN integration (including O(pen)RAN integration), Satellite/Non-terrestrial Networks and 5G/6G integration, as well as AI/ML based 5G/6G network control and management.

For more details and a longer version look here:

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## Forewords

### **Henning Schulzrinne, Columbia University, USA**

The first few iterations of cellular networks, 1G through 3G, were largely telephone networks with mobility added on, including the choice of addressing through telephone numbers, signaling through SS7, and emphasis on interoperable voice services. 4G and 5G started the transition to an Internet-driven architecture, with remnants of the old architecture still clearly visible. But beyond the protocol choices, all existing generations were largely driven by the assumption that networks are operated by a relatively small number of carriers, typically with at least a nationwide service footprint, reliant on licensed spectrum and an assumption of mutual trust. 5G has started to focus more attention on using the same radio technology for both industrial and consumer networks, but the large-carrier mindset still pervades the design, with a tightly-coupled set of protocols and entities. This tightly-coupled model provides some advantages; it bundles a consistent set of features and technologies designed and packaged to work together, relying on a strict user management and authentication framework. However, this model comes also with drawbacks, such as the lack of flexibility to adapt to new technologies or use-cases, and having to rely on three or at most four carriers in most countries.

Since 3G, branding mobile network generations have had both a technical and a consumer marketing role. The generations provided checkpoints for equipment vendors, and made advances in technology that's otherwise largely invisible to consumers relevant and marketable. 5G is probably the first iteration where a transition in technology standards became a matter of national pride and an

indicator of national or regional competitiveness, with promises of increases in consumer and societal welfare that may be hard to deliver. However, as the digital divide during COVID-19 illustrated, universal access to affordable broadband, typically at home, mattered more than higher 5G speeds in the downtown business districts and digital transformation is not assured by having nationwide 5G. Thus, technologists and policy makers working on post-5G efforts should be careful in calibrating expectations, given that wireless network technology may not be the most significant hurdle that prevent addressing key societal challenges.

It seems likely that we will see a much larger variety of operational scenarios in the next decade, from traditional vertical-integrated carriers to disaggregated carriers and to private or federated enterprise networks. Any future network architecture needs to be sufficiently modular so that it can scale down to unmanaged home networks and scale up to networks where participants have limited trust in each other. This suggests a much more flexible and much simpler authentication and roaming model than we have had in previous network generations. Here, 6G can probably learn from another wireless technology where “generations” have played less of a role – ubiquitous Wi-Fi.

Developments for IoT during the 5G standardization and deployment phase may also hold lessons that encourage predictive modesty for 6G. Rather than being the universal network that connects billions and billions of IoT devices to create “smart” buildings and cities, cheap home Wi-Fi and new low-cost technologies like LoRa, leveraging unlicensed spectrum, have come to dominate, with carrier IoT offerings falling short of expectations – indeed, retaining boring and obsolete 2G often seems to draw more interest than new 5G ultralow latency capabilities.

Previous generations of cellular networks offered their per-user speed as the headline advantage, but 5G is already showing the limitations of that approach, as few mobile applications are likely to be built that will rely on 1 Gb/s or above speeds. Thus, the key metrics will not be per-user throughput or latency, but cost per base station month, governing deployment cost in low-density areas, and cost per bit delivered, i.e., primarily operational costs.

Environmental metrics such as energy consumption or electromagnetic fields (EMF) must also be considered. For many years, capital equipment has only accounted for about 15% of revenues of most carriers, i.e., the vast majority of expenses are operational. This argues for a simple, self-managed, and robust network, with as many commodity components and protocols as possible and as much re-use of available fiber access networks as possible, rather than infinite configurability or elaborate QoS mechanisms. The largest opportunities for improved operational efficiency and reduced complexity are in the control plane, not the data plane, relying for that on machine learning and automation technologies as detailed in this book. However, since 6G will serve as infrastructure, with concomitant reliability expectations, robustness, predictability and explainability of any use of machine learning will be more important than squeezing out the last percentage points of efficiency.

Despite all the changes in technology, the common thread across mobile technology generations has been a dramatic reduction in the consumer unit cost of mobile data, with new applications enabled simply because they became affordable. Thus, 6G will likely only offer a significant value proposition beyond a marketing tag line if it is engineered to minimize operational complexity, maximizes operational automation and ensures high availability. The Wi-Fi experience can offer lessons and might even offer an