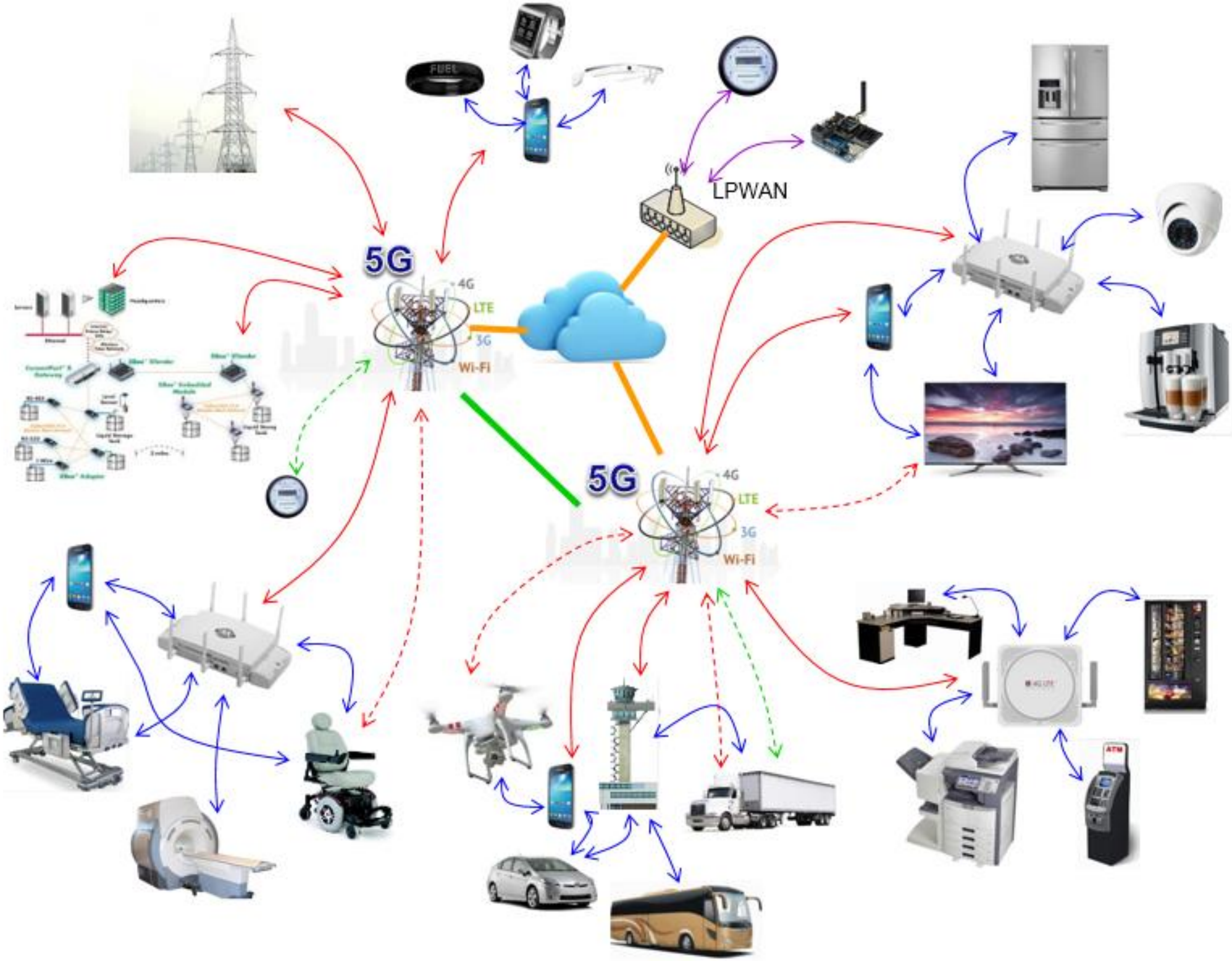
Networks and Communication

Introduction

- Present communication technologies span the globe in wireless and wired networks and support global communication by globally-accepted communication standards.
- The Internet of Things **Strategic Research and Innovation Agenda (SRIA)** intends to lay the foundations for the Internet of Things to be developed by research through to the end of this decade and for subsequent innovations to be realised even after this research period.
- Everything will change significantly.
- Changes will first be embedded in given communication standards and networks and subsequently in the communication and network structures defined by these standards.

IoT & Applications (18EI2T09)



Networking Technology

- Mobile traffic today is driven by **predictable** activities such as making calls, receiving email, surfing the web, and watching videos.
- Over the next 5 to 10 years, billions of IoT devices with **less predictable traffic patterns will join the network, including vehicles, machine-to-machine (M2M) modules, video surveillance that requires all the time bandwidth, or different types of sensors** that send out tiny bits of data each day.
- The **rise of cloud computing** requires new network strategies for fifth evolution of mobile the 5G, which represents clearly a convergence of network access technologies.
- The architecture of such network has to **integrate the needs for IoT** applications and to offer seamless integration. To make the IoT and M2M communication possible there is a need **for fast, high-capacity networks.**

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- 5G networks will deliver **1,000 to 5,000 times more capacity** than 3G and 4G networks today and will be made up of cells that support peak rates of between **10 and 100Gbps**.
- They need to be **ultra-low latency**, meaning it will take data 1–10 milliseconds to get from one designated point to another, compared to 40–60 milliseconds today.
- Another goal is to separate communications infrastructure and allow mobile users to move **seamlessly** between 5G, 4G, and WiFi, which will be fully integrated with the cellular network.
- Networks will also increasingly become **programmable, allowing operators to make changes to the network virtually, without touching the physical infrastructure**.

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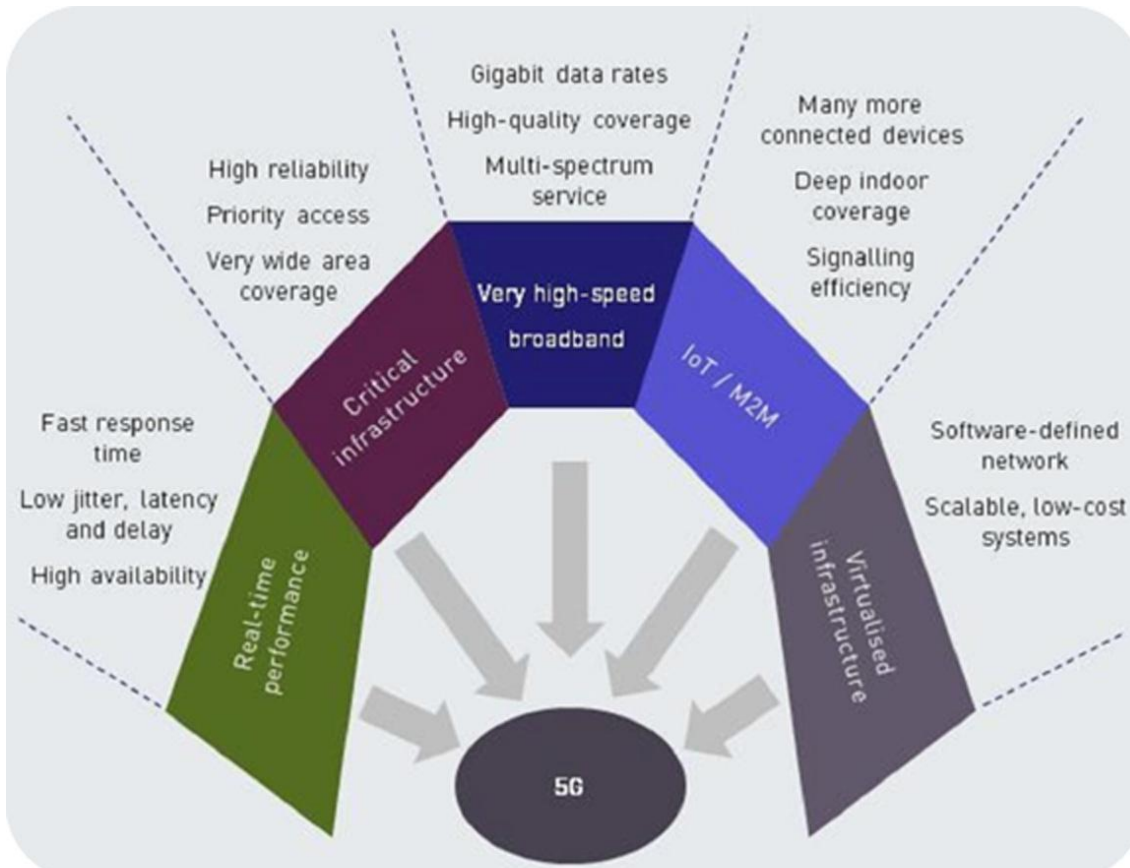

[5G Features]

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- **Complexity of the networks of the future**
  - A key research topic will be to understand the complexity of these future networks and the expected growth of complexity due to the growth of Internet of Things.
  - The research results of this topic will give guidelines and timelines for defining the **requirements for network functions, for network management, for network growth and network composition and variability**.
  - Wireless networks cannot grow without such side effects as **interference**.

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- **Growth of wireless networks**
  - Wireless networks especially will grow largely **by adding vast amounts of small Internet of Things devices with minimum hardware, software and intelligence**, limiting their resilience to any imperfections in all their functions.
  - **Based on the research of the growing network complexity**, caused by the Internet of Things, **predictions of traffic and load models will have to guide further research on unfolding the predicted complexity to real networks**, their standards and on-going implementations.
- **Mobile networks**
  - Applications such as body area networks may develop into an autonomous world of small, mobile networks being attached to their bearers and being connected to the Internet by using a common point of contact.
  - The mobile phone of the future could provide this function.

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- **Expanding current networks to future networks**
  - Generalizing the examples given above, the trend may be to expand current end user network nodes into networks of their own or even a hierarchy of networks.
  - In this way networks will grow on their current access side by unfolding these outermost nodes into even smaller, attached networks, spanning the Internet of Things in the future.
- **Overlay networks**
  - Even if network construction principles should best be unified for the worldwide Internet of Things and the networks bearing it, there will not be one unified network, but several.
  - In some locations even multiple networks overlay one another physically and logically.
  - The Internet and the Internet of Things will have access to large parts of these networks.

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- **Network self-organization**
  - Self-organization principles will be applied to configuration by context sensing, especially concerning autonomous negotiation of interference management and possibly cognitive spectrum usage, by optimization of network structure and traffic and load distribution in the network, and in self-healing of networks.
  - All will be done in heterogeneous environments, without interaction by users or operators.
- **IPv6, IoT and Scalability**
  - The current transition of the global Internet to IPv6 will provide a **virtually unlimited number of public IP addresses** able to provide bidirectional and symmetric (true M2M) access to Billions of smart things.
  - It will show the way to new models of IoT interconnection and integration.

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- **Green networking technology**
  - Given the enormous expected growth of network usage and the number of user nodes in the future, driven by the Internet of Things, there is a real need to minimize the resources for implementing all network elements and the energy being used for their operation.
  - In recent years shows that networks can achieve an **energy efficiency** increase of a factor of 1,000 compared to current technologies

Communication Technology

- **Unfolding the potential of communication technologies**
  - The research aimed at communication technology to be undertaken in the coming decade will have to develop and unfold all potential communication profiles of Internet of Things devices, from **bit-level communication to continuous data streams, from sporadic connections to connections being always on, from standard services to emergency modes, from open communication to fully secured communication, spanning applications from local to global, based on single devices to globally-distributed sets of devices.**
- **Correctness of construction**
  - Correctness of construction of the whole system is a systematic process that starts from the **small systems running on the devices up to network and distributed applications.**
  - Methods to prove the correctness of structures and of transformations of structures will be required, **including protocols of communication between all levels of communication stacks** used in the Internet of Things and the Future Internet.
  - These methods will be essential for the Internet of Things devices and systems, as the smallest devices will be implemented in hardware and many types will not be programmable.

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- **An unified theoretical framework for communication**
  - Communication between processes running within an operating system on a single or multicore processor, communication between processes running in a distributed computer system, and the **communication between devices and structures in the Internet of Things and the Future Internet using wired and wireless channels shall be merged into a unified minimum theoretical framework covering and including formalized communication within protocols.**
  - In this way **minimum overhead, optimum use of communication channels and best handling of communication errors should be achievable**.
- **Energy-limited Internet of Things devices and their communication**
  - Many types of Internet of Things devices will be connected to the energy grid all the time; on the other hand a significant subset of Internet of Things devices will have to rely on their own limited energy resources or energy harvesting throughout their lifetime.
  - Given this spread of possible implementations and the expected importance of minimum-energy Internet of Things devices and applications, an important topic of research will have to be the search for minimum energy, minimum computation, slim and lightweight solutions through all layers of Internet of Things communication and applications.

Processes

Introduction

- The deployment of IoT technologies will significantly impact and change the way enterprises do business as well as interactions between different parts of the society, affecting many processes.
- To acquire the potential benefits that have been postulated for the IoT, several challenges regarding the modelling and execution of such processes need to be solved in order to see wider and in particular commercial deployments of IoT.
- The special characteristics of IoT services and processes have to be taken into account.

Adaptive and Event-Driven Processes

- One of the main benefits of IoT integration is that processes become more adaptive to what is actually happening in the real world.
- Inherently, this is based on events that are either detected directly or by real-time analysis of sensor data. Such events can occur at any time in the process.
- For some of the events, the occurrence probability is very low: one knows that they might occur, but not when or if at all.
- Modelling such events into a process is very difficult, as they would have to be included into all possible activities, leading to additional complexity and making it more difficult to understand the modelled process, in particular the main flow of the process.
- Secondly, how to react to a single event can depend on the context, i.e. the set of events that have been detected previously.

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- Research on adaptive and event-driven processes could consider the extension and exploitation of EDA (Event Driven Architectures) for activity monitoring and complex event processing (CEP) in IoT systems.
- EDA could be combined with business process execution languages in order to trigger specific steps or parts of a business process.

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