TNO’s Mission

TNO connects people and knowledge to create innovations that boost the sustainable competitive strength of industry and well-being of society.

‘Innovation for Life’

- Developing fundamental knowledge: With universities
- Knowledge development: With partners in the golden triangle
- Knowledge application: Contract research for and with customers
- Knowledge exploitation: Embedding in the market (with TNO companies)
TNO IS ACTIVE IN THE DEVELOPMENT OF 5G

TECHNOLOGY RESEARCH PROJECTS

- 5G standardisation
- SDN/NFV technology
- Heterogeneous networks

VERTICAL/ ECOSYSTEM RESEARCH PROJECTS

- 5G & net neutrality
- Real-time ITS using cellular communication
- Future indoor wireless ecosystem models

(PRE-) 5G FIELDLABS
Hi5 is not just a lab, it is a **flexible environment** based on OpenSource components that can support all kinds of trials, experiments and test in all kinds of locations.

Hi5 helps us to study, develop and trial **new network concepts** (core, radio, SDN/NFV, security), **new service capabilities** (IoT, multimedia services, vehicle to vehicle), and explore new **business models** (multi-tenancy).
5GRONINGEN

- Initiative to develop a 5G Fieldlab in the rural area in the north of Groningen
  - Partners: KPN, Vodafone, Huawei, Ericsson, TNO, Agentschap Telecom, SURF, RUG, Hanzehogeschool, Economic Board Groningen
- Use cases for 5G in five “verticals”
  - Agriculture, Health, Energy, Mobility&Logistics, Environment&Sustainability
- More information: http://www.5groningen.nl
The “Monitor Draadloze Technologie” provides an overview of developments in wireless technology.

- Aim is to inform Dutch professionals with an interest in telecommunications.
- April issue: developments in wireless technologies.
- October issue: developments in application domains of wireless technology.

PART 1

5G
EC GIVES BOOST TO 5G INTRODUCTION

5G FOR EUROPE ACTION PLAN LAUNCHED ON 14 SEPTEMBER 2016

- 5G commercially available in at least one major city in every EU member state by end 2020.

- 5G trials to take place from 2017 onwards.

- Identify provisional 5G spectrum bands by end 2016 and full set of 5G spectrum bands by end 2017.

- Uninterrupted 5G coverage for all urban areas and all major terrestrial transport paths by 2025.
Planned 5G networks are expected to serve up to one million connected devices per km².

Very dense network of 5G access points is required to deliver planned performance.
  - Increasingly smaller cells and increasing density of antennae.
  - Small cells need high capacity backhaul connections. In most cases these will be fiber links.

Key priority is to facilitate the speedy and cost-effective deployment of small cells by removing deployment barriers and coordinating cellular and fiber infrastructures.
5G TECHNOLOGY WILL NOT ONLY KEEP UP WITH CAPACITY GROWTH …

- At the start of the 5G time frame, mobile operators will have to deal with \textbf{1000x more data traffic} and \textbf{10x more connected things} compared to at the start of LTE.

- 5G technology is needed to provide the additional capacity \textbf{without a proportional increase of costs}. 

\begin{itemize}
  \item [\textbf{Figure}]
  \item \textbf{Source: ARIB}
\end{itemize}
... 5G WILL ALSO ENABLE NEW SERVICES

From Communications to Control

- Automated driving
- Industrial sensor/actuator system
- Remote content management
- Real-time distribution

Ultra Reliable

- Emergency services
- Business Service Level Agreements
- Control network for a country’s entire infrastructure

Cloud & Smart Edge

- Distributed & centralised
- Low latency local content & control
- Tactile internet

Source: Vodafone 3GPP SA1 contribution
5G REQUIREMENTS / TARGETS

Source: 5G-PPP
5G USE CASES

Enhanced Mobile Broadband
- Gigabytes in a second
- 3D video, UHD screens
- Work and play in the cloud
- Augmented reality
- Industry automation
- Mission critical application, e.g. e-health
- Self Driving Car

Massive Machine Type Communications
- Million devices per km²

Ultra-reliable and Low Latency Communications
- Mission critical

Future IMT

High bitrates

Source: ITU-R
5G OFFERS MULTI-PURPOSE, FLEXIBLE NETWORK

- Unified multi-purpose physical network which can be "sliced" to serve a variety of different use cases.
- Specific network instances optimised for specific customers, service scenarios and/or terminal types.
- Enables true fixed-mobile convergence: seamless experience within single domain for fixed & mobile.
DRIVERS FOR INDOOR WIRELESS

- 80% of mobile traffic originates from indoors (Ref: CommScope).

- Almost all vertical industries addressed by 5G rely on high coverage/capacity indoors.
  - Smart factories, Smart homes, Offices, e-Health, mission critical services.

- In-building wireless market predicted to be worth $16.71 billion in 2020 (Ref: marketsandmarkets.com).

- However, only 2% of buildings right now have dedicated in-building cellular systems (Ref: CommScope).
INDOOR WIRELESS
WHAT DO BUILDING PROFESSIONALS THINK?

- Fewer than half of architects across the globe plan and design buildings with dedicated in-building cellular networks in mind.

- Who is responsible for ensuring indoor wireless connectivity?
  - Over 33% of respondents: Network operators
  - 25% of respondents: IT managers
  - 20% of respondents: Building managers

- Top three roadblocks standing in the way of providing indoor wireless connectivity
  - 35% of respondents: Cost of the network
  - 19% of respondents: Complexity of the technology
  - 11% of respondents: Lack of skilled workers to manage it

Source: CommScope
In-building wireless survey 2016, in which 600 building professionals were interviewed across the U.S. and Europe.
INDOOR COVERAGE/CAPACITY: SEVERAL SOLUTIONS
ALL WITH THEIR RELATIVE BENEFITS AND CHALLENGES

Strategic option | Solution | Details
---|---|---
Macro extensions | Add new carriers | Add new frequency bands
 | Interference management | Optimise azimuth/tilt and intercell coordination
 | Add new sectors | Horizontal and vertical sectorisation
Outdoor densification | Micro & pico | Adds coverage at macro cell edges and hotspots
 | RRH | Fiber fronthaul to existing macro sites
Indoor solutions | Small cells | Increase capacity at indoor/outdoor hotspots
 | Wi-Fi | Data offloading from the cellular network
 | Dedicated indoor system | Coverage of large-sized buildings
MARKET INITIATIVES TO INCREASE CAPACITY

- Operators are extending capacity in their networks, especially in dense urban areas due to rapid increase in data consumption.

- Examples in the Netherlands.
  - Carrier aggregation.
  - Densification (adding more sites/sectors) including small cells in busy inner city areas.
  - Dedicated in-building solutions are also offered in the market, e.g. DAS systems.

- Challenge for deploying dedicated indoor solutions is the cost and complexity ("business case").
WHAT 5G MEANS FOR INDOOR DEPLOYMENTS

KEY MESSAGES

- **Densification** and **indoor deployments** (e.g. dedicated indoor systems and small cells) are **essential components** to deliver on the ambitious targets of 5G.

- 5G places significant demands on supporting (transport network) infrastructure and therefore the 5G architecture will need to be as **fiber rich** as existing fixed networks.

- 5G should enable a **unified infrastructure** for fixed/mobile in buildings.

- Indoor deployments need to be **future-proof** and **scalable** to allow introduction of 5G.
  - Otherwise there may be **wasted** investments.
  - Cooperation among stakeholders is essential.
5G BRINGS ULTRA DENSE NETWORKS

- 5G will be delivered using a wide range of spectrum bands.
  - Includes high frequencies.

- High capacity and high data rates at high frequencies implies a lot of very small base stations
  - Small cells
  - Indoor deployment

(Source: Qualcomm)

(Source: METIS)
5G WILL USE MILLIMETRE WAVES ...  
**ESPECIALLY RELEVANT FOR INDOOR DEPLOYMENTS**

- More capacity will be provided by 5G due to the use of a **large amount of spectrum** in mmWave bands.

- Enables **higher peak user throughput** because of the large bandwidths.

<table>
<thead>
<tr>
<th>Spectrum band</th>
<th>Expected carrier bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-4 GHz</td>
<td>100 MHz</td>
</tr>
<tr>
<td>5-33 GHz</td>
<td>500 MHz</td>
</tr>
<tr>
<td>&gt; 33 GHz</td>
<td>1000 MHz</td>
</tr>
</tbody>
</table>

(Source: 5G-PPP)

(Source: FP7 MiWEBA)
... BUT MILLIMETRE WAVES BRING SEVERAL CHALLENGES

- Higher propagation and penetration loss (including body loss).
  - Beamforming with highly directional antennas is required.
  - Coverage range up to ~200 metres claimed to be possible.

- At higher frequencies device power consumption increases due to lower power amplifier efficiency and large number of antenna elements.
4G/5G INTEGRATION WITH UNLICENSED BANDS

Source: Qualcomm
Centralised base band unit (BBU) pools and distributed remote radio heads (RRHs) connected via a high bandwidth and low latency fronthaul.

Potential savings:
- reduced site rental and O&M costs
- multiplexing gains
- higher energy efficiency (less air conditioning);
- facilitate inter-cell collaboration.

... BUT CLOUD RAN ALSO HAS CHALLENGES
HUGE FRONTHAUL CAPACITY IS REQUIRED INCLUDING INDOORS

- Potentially tens or hundreds of Gbps fronthaul connection required.
- Very stringent latency/jitter requirements too.

Source: Netmanias.com
PART 3
KEY CONCLUSIONS
KEY CONCLUSIONS

- 5G is in a rapid development phase. The recently announced European Commission 5G for Europe Action Plan sets ambitious targets for the deployment of 5G.

- 5G promises to not only significantly boost **data capacity and throughput** but also support **vertical services** which have a diverse range of requirements.

- Several components of 5G are **relevant for indoor deployments** including ultra dense networks, mmWave technologies, integration with unlicensed spectrum bands and Cloud RAN.

- To achieve ambitious 5G targets (e.g., 10 Gbps peak throughput, 1 ms latency, 99.999% reliability) there needs to be **sufficient transport capacity** (i.e. fiber), including within buildings.
  - Cooperation among stakeholders is essential: building owners, operators, equipment manufacturers, government.
THANK YOU FOR YOUR ATTENTION