Smart Connectivity Panel
EUCNC 2018

Panel Chair: Arturo Azcorra

[Developing the Science of Networks]
Communications in the years 2021-27

- ICT represents ~5% of EU GDP, or €600 billion
- 5G M2M/IoT will imply $4 trillion to $11 trillion by 2025
- 5G-based European Digital Market will contribute over €4 billion to the EU Economy
- Supercopmuting, Machine Learning and Blockchain will impose even MORE demanding requirements on the networks
- Visions for Future Communications Summit, Oct 2017 Lisbon
- Strategic Research and Innovation Agenda 2021-27 from Networld 2020 ETP and 5G-IA
Dr. Diego López, Telefonica I+D, Spain

- Dr Diego R. López joined Telefonica I+D in 2011 as a Senior Technology Expert on network middleware and services. He is currently in charge of the Technology Exploration activities within the GCTIO Unit of Telefónica I+D. Before joining Telefónica he spent some years in the academic sector, dedicated to research on network service abstractions and the development of APIs based on them. During this period, he was appointed as member of the High-level Expert Group on Scientific Data Infrastructures by the European Commission.

- Dr Lopez is currently focused on identifying and evaluating new opportunities in technologies applicable to network infrastructures, and the coordination of national and international collaboration activities. His current interests are related to network virtualization, infrastructural services, network management, new network architectures, and network security. He chairs the ETSI ISG on Network Function Virtualization, and the NFV Research Group within the IRTF. He has published more than 100 papers and supervised several PhD theses on the matters related to Software Networks, network security and network middleware.
Prof. Serge Fdida is a Professor with Sorbonne Université (formerly UPMC) since 1995. His research interests are related to the future internet technology and architecture. He has been leading many research projects in Future Networking in France and Europe, notably pioneering the European activity on federated Internet testbeds. He is currently leading the Equipex FIT, a large-scale testbed on the Future Internet of Things. Serge Fdida has published numerous scientific papers, in addition to a few patents and one RFC. He is a Distinguished ACM Member and an IEEE Senior member.

Serge Fdida has also developed a strong experience related to innovation and industry transfer, - he was the co-founder of the Qosmos company, - one of the active contributor to the creation of the Cap Digital cluster in Paris. He has been appointed Vice-President Europe and International affairs at Sorbonne from 2011 to 2017.
Werner Mohr was graduated from the University of Hannover, Germany, with the Master Degree in electrical engineering in 1981 and with the Ph.D. degree in 1987. He joined Siemens AG, Mobile Network Division in Munich, Germany in 1991. He was the coordinator of the WINNER Project, chairman of WWI (Wireless World Initiative) and of the Eureka Celtic project WINNER+. The WINNER projects laid the foundation for the radio interface for IMT-Advanced and provided the starting point for the 3GPP LTE standardization. He was vice chair of the eMobility European Technology Platform in the period 2008 - 2009 and chairperson of the Net!Works (formerly called eMobility) chairperson for the periods 2010 - 2011 and 2012 - 2013. He was elected in December 2013 as chairperson of the new communications networks related ETP NetWorld2020 for the period until December 2016, which was launched in October 2013 based on the former Net!Works ISI ETPs.

Werner Mohr has been the Chair of the Board of the 5G Infrastructure Association as part of 5G PPP of the EU Commission from its start in November 2013 until December 2016. Werner Mohr was chair of the "Wireless World Research Forum - WWRF" from its launch in August 2001 up to December 2003. Werner Mohr is co-author of a book on "Third Generation Mobile Communication Systems" a book on "Radio Technologies and Concepts for IMT-Advanced" and a book “Mobile and Wireless Communications for IMT-Advanced and Beyond”. In December 2016 Werner Mohr received the IEEE Communications Society Award for Public Service in the Field of Telecommunications.
Prof. Dimitra Simeonidou, Bristol University, UK

• Prof. Dimitra Simeonidou is Full Professor at the University of Bristol, the Director of the Smart Internet Lab, Chief Scientific Officer (CSO) of Bristol Is Open and Head of the High Performance Networks group (HPN). Her research is focusing in the fields of High Performance Networks, Network Convergence, Software Defined Networking and Smart City infrastructures. She is the author and co-author of over 400 publications, numerous patents and several major contributions to standards.

• She has been co-founder of two spin-out companies, the latest being the University of Bristol VC funded spin-out Zeetta Networks, http://www.zeetta.com, delivering SDN solutions for enterprise networks.

• Since 2015 she has been the Technical Lead of the smart city test-bed project Bristol Is Open (www.bristolisopen.com). Dimitra is a Royal Society Wolfson scholar
Prof. Arturo Azcorra, IMDEA/UC3M, Spain

- Director of IMDEA Networks
- Professor at University Carlos III of Madrid
- President of the 5TONIC 5G Laboratory
- Chairman of the Expert Advisory Board of Networld 2020 ETP
Challenges to be developed in this panel

1. What will be the **key technological elements** of Smart Connectivity?
2. What will be the **control and data planes** of Smart Connectivity?
3. What will be the **radio characteristics** of Smart Connectivity?
4. What will be the **challenges for a widespread deployment** of Smart Connectivity?
5. What role will **European companies and academia** have in the **world market** of Smart Connectivity?

**TEN MINUTE** presentation by each panelist
Making the Network Smart in All Good Senses
Intelligent, Fast and Stylish

Diego R. Lopez
Telefónica
Key Technology Elements

(Radio Ones Intentionally Excluded)

- **Software Networks**
  - Whatever the flavor: SDN, NFV, SDWAN, IBN...
  - The essential substrate
  - A solution continuum, connected with cloud space

- **Orchestration**
  - A multi-layer, holistic approach
  - At several levels
  - Separation of concerns through appropriate views

- **Closed-loop control**
  - Well know in (most) other industries
  - End-to-end automation

- **Data-driven management**
  - Not only AI or ML
  - The whole data flow

- **Distributed systems**
  - As ever
  - Aligned with orchestration
The Planes

- Fully programmable data plane
  - Integrated with orchestration mechanisms
  - Software images of different nature
  - Composition beyond tunneling
  - Trusted (secure and attested) channels

- Composable control plane
  - Dynamic integration
  - Authentication, authorization, accountability
  - Intent at the NBI

- Challenging IP pervasiveness
  - Time for other network protocols
  - Or even protocol obliviousness

- And a monitoring plane
  - Essential for data-driven management
  - Provenance, continuity
Radio Characteristics

- **A completely converged** network
  - Software-based at all segments
  - Consistently orchestrated
  - Providing end-to-end abstractions
- And that includes the radio elements
  - What means a long path to go
Challenges

- The scale issue
- Convergence of software network paradigms
- Bridging the gap between IT and network practices
- Security and trust management
- Proper abstractions
- The dialectics matter

- Frameworks vs architectures
- Making open source and standards converge
- The industry culture
- Regulation
- Sustainability
The European Role

- Telecoms is one of the few industrial areas with European leadership
  - It is about keeping it
- The smarter the network the fuzzier the borders between it and applications/services/clouds/…
  - A huge opportunity and a huge risk
- Further research is required to achieve Smart Connectivity
  - Remember: in all good senses
- And to cross the “Death Valley”
  - Applied research is key here
- Rethink the models
  - EC-funded programs
  - The startup frenzy
Smart Connectivity in the context of Next Generation Internet

Serge Fdida, Sorbonne Université & CNRS

EUCNC – June 2018
What will be the key technological elements of Smart Connectivity?

Supporting infrastructure to cope with latency, storage, and computation
What will be the control and data planes of Smart Connectivity?

• “The Network is a Database”, S. Fdida
  NextWorking 2007 (Joint Cost-NSF workshop)

Networking Named Content, Van Jacobson,
Conext 2009 and others ….

• “Who cares about packets”?

• Distributed Publish-Subscribe model
  (a federated service bus)

• Distributed: Federated Control Planes
What will be the radio characteristics of Smart Connectivity?

• 3D: Dynamic, Diversity, Dense
What will be the challenges for a widespread deployment of Smart Connectivity?

- The disappearing Network
- Acceptance of Massive Wireless
- Should be fully integrated in the service
- Management and costs
What role will European companies and academia have in the world market of Smart Connectivity?

- *The Network will disappear*
- Solutions to seamless integration of network components
- Risk taking
- Development, testing, pilots
- Tools to support the design of digital infrastructures
Smart connectivity in the context of Next Generation Internet

EuCNC 2018, Panel 3
June 21, 2018, Ljubljana
Werner Mohr
What will be the key technological elements of Smart Connectivity?

Smart Networks vision

Smart connectivity and network architecture will be software defined and provide features significantly beyond connectivity:

- **Multiservice and Mobile Edge Computing**: Store and process data locally at network edges to provide fast reactions and efficient use of network resources
- **Programmable aggregation, virtualisation and built-in security functions**: Create trusted environment for the Internet of smart things (e.g. support of blockchains)
- **Future cost-effective communication systems and networks**: Increasingly based on Artificial Intelligence (AI), Machine Learning (ML) and softwarisation

- Communication infrastructure is nervous system of the Human Centric Internet and digital transformation
- Distributed network, compute and storage resources to facilitate agile composition of new services supporting a multitude of markets and industry sectors
- Every system and application must be interconnected to its peers
  - From supercomputers and parallel computers, to data analytics,
  - passing through cybersecurity,
  - the Internet of Things (IoT),
  - cooperative robots, or autonomous vehicles
What will be the key technological elements of Smart Connectivity?

Key-enabling technologies and requirements

- Trustworthy Smart Communication technologies
- Software technologies
- Artificial Intelligence and Machine Learning
- Cybersecurity

- **Radio technology and signal processing**: Spectrum re-farming and reutilisation; Millimeter Waves; Optical wireless communications; Terahertz communications including new materials (graphene); Ultra-massive MIMO; Non-orthogonal carriers; Enhanced modulation and coding; Improved Positioning and Communication; Random access for massive connections; Wireless Edge Caching for Further Increased Throughput

- **Optical networks**: Flexible capacity scaling; New switching paradigms; Deterministic networking; Optical wireless integration; Optical network automation; Security for mission critical services; Ultra-high energy efficiency; Optical integration 2.0

- **Communication satellite technologies**: Enabled services; Ground segment; Space segment; Communication architectures; Convergence with heterogeneous networks

- **Future and emerging technologies**: Nano and bio-nano things and networks
What will be the control and data planes of Smart Connectivity?

Baseline network slicing

- Flexibility
- Support of many different application domains
- Provision of different virtual networks on same physical infrastructure
- Separation between control and data plane for independent scaling and flexible function placement

What will be the radio characteristics of Smart Connectivity?

Generic considerations

• **Seemingly infinite network capacity:** Additional frequency bands, e.g. Terahertz domain and visible light communication

• **Imperceptible latencies beyond 5G requirements:** New class of highly responsible and interactive applications and new level of industrial automation

• **Massive amounts of things and systems** to be connected in scalable and cost-efficient way

• **Very short-range communication:** Nano and bio-nano things and networks

• **Global reach and optimised local service delivery capabilities** need to be combined in highly flexible ways and should be available on-demand

• **Cognitive operations making use of Artificial Intelligence and Machine Learning** mechanisms combined with cyber physical security are required to cope with the growing complexity of networks and systems

• **Personalised and perpetual protection:** Security, privacy and trust mechanisms to cover
  - expanding threat surface due to billions of IoT devices and
  - to deal with the growing number of threats triggered by increasing value of data
What will be the challenges for a widespread deployment of Smart Connectivity?

- General considerations independent of radio system for high area system capacity and not only coverage provision

\[ L_p = A_d \cdot \log r + A_f \cdot \log f + \text{const} \]

\[
\left( \frac{r_1}{r_2} \right)^2 = \left( \frac{B_2}{B_1} \right)^{\frac{20}{A_d}} \cdot \left( \frac{f_2}{f_1} \right)^{\frac{2\cdot A_f}{A_d}} = \frac{N_{BS,2}}{N_{BS,1}}
\]

- \( r \) – distance between mobile and base stations
- \( f \) – carrier frequency
- \( A_d \) – path loss coefficient for distance
- \( A_f \) – path loss coefficient for carrier frequency
- \( B \) – bandwidth or throughput
- \( N_{BS} \) – number of base stations

- General considerations independent of radio system (terrestrial, satellite or HAPS)
  - \( B \uparrow \) results in \( r \downarrow \) and \( N_{BS} \uparrow \)
  - \( f \uparrow \) results in \( r \downarrow \) and \( N_{BS} \uparrow \)

- Challenges for high throughput systems
  - Huge number of base stations \( N_{BS} \)
  - Very dense terrestrial backbone network or very high throughput satellite/HAPS backbone \( n \cdot B \) to serve one footprint cell (area capacity limitations)
  - Multi-antenna concepts increase range and capacity (massive MIMO)
  - Significant economic impact on deployment cost
What role will European companies and academia have in the world market of Smart Connectivity?
What role will European companies and academia have in the world market of Smart Connectivity?

- European industry is serving the global market
- Impact in the global market
  - Research and development of future systems and solutions
  - IPR generation and know how development
  - Contribution to and shaping of international standardisation
  - Support of cooperation of different industries towards digital transformation
- European academic community is part of global research community
  - Participation in global research cooperation and information exchange
  - Cooperation with industry partners and international partners especially in collaborative research
- European companies and academia play important role in global ICT development
- However, Europe is challenged by other regions in specific ICT areas of research and market penetration
- Therefore, increased investment in collaborative research in Horizon Europe essential for future European economy, job creation and growth
5G and Beyond

Dimitra Simeonidou
Director Smart Internet Lab, University of Bristol
June 2018
Key Technological Elements for Smart Connectivity

Manage a diverse “Network-of-Networks”
IT & Telecoms, Wireless, Optical, IoT, data, digital vertical sectors, etc.

Seamless Convergence

Technology & Vendor Agnostic
Real time abstractions of the underlying hardware
Infrastructure Virtualisation

xG ++, commodity hardware

Customized and Automated
Customize virtual resource provisioning per vertical,
optimum service delivery per application,
slicing, orchestration, NFV, PNF, AI, ML

Programmable
Control & Data Plane for Smart Connectivity: Towards Network Infrastructure as a Utility

Challenges:
- Extreme heterogeneity
- Extreme granularity
- Open platform ecosystem for cloud, network and data resources (multi-ownership)
- Agility and responsiveness
- At scale

New ways for managing infrastructure and services:
- New Infrastructure composition and programing models
  - Distributed and disaggregated
  - Network connectivity as backplane
  - Aggregation to achieve complex infrastructures
  - Automation
  - Advanced Monitoring and Machine Learning techniques
  - Programmable hardware- on hardware ML
Network Hardware Characteristics for Smart Connectivity: Generalized Convergence - One Hardware any Function

Programmable Electronic Backplane

- Resource Controller
- Switching functions:
  - Ethernet/TDM Switchover
  - Ethernet Switch
  - Elastic TDM Switch
- Physical technology drivers and Transmission
- Switch control
- Network function blocks:
  - Flexi TDM Switch
  - MUX/DEMUX
  - Switch
  - Multicasting
- System operations:
  - Aggregation
  - TDM Frames/slots
  - QoT Overhead
- Node Function blocks
- Nodes Synchronization

Optical Backplane

- Amplification
- Programmable Electronic Backplane

Internet of Things

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Widespread Deployment of Smart Connectivity

- New infrastructure management and service provisioning models
- Neutral hosting
- Open to foster innovation
- Spectrum brokering operators?
- Digital service providers?
- Commercial models for data
- Responsible & ethical
- Focus on enterprise, logistics and retail

Diagram:
- Depth of Sharing
- Scope of Sharing
- Assets of Sharing
- Number of Sharing Parties
- O&M of Sharing
- Technology
  - 5G
  - 4G
  - 2G
  - WiFi
  - Fibre
- Convergence
- Site share
- Digital Infrastructure
-Network JV
- City
- District
- National

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The Role of European Companies and Academia

CROSS SECTOR CHALLENGES
& INNOVATION SECTORS

PLAY OUT FOR VALUES
UNDERLYING SOCIAL
CONTEXT:
CITIZENS
BUSINESS
SME’S
INCLUSIVITY
RESPONSIBILITY
ETHICS
WORKING MODELS

WE’RE INTERESTED IN
UNDERSTANDING
THE LONG TERM
FUTURES

BUSINESS MODELS:
PARTNERSHIP FRAMEWORKS
ACCESSIBILITY TO RESOURCE
AGILITY
REGULATION
SMART TRANSACTIONS
IPR

SECTORS:
HEALTH
TRANSPORT
DIGITAL
CREATIVE
MANUFACTURING
CITIES
ENVIRONMENT/
SUSTAINABILITY
LIVING WELL

THE FUTURE

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