The Energy Efficiency Challenge in the EC H2020 5G Infrastructure PPP

Dr. Didier Bourse

01.10.14 - Next GWIN 2014 - Rennes

Alcatel·Lucent

Key Note Outline

- ALU BL EU Research Cooperations Framework
- 5G ALU Perspectives
- 5G Infrastructure PPP in a Nutshell
- 5G Infrastructure PPP Pre-structuring Model
- 5G Infrastructure PPP EE 90% KPI

ALU BL EU Research Cooperations Framework (1/2)

Framework & Ecosystem (Highlights)

ETPs

Net!Works

PHOTONICS21

EIT KIC

FET
ERC
Marie-Curie
(MSCA)

CIP

Large (IPs) & Small (STREPs) Projects
CSAs, NoEs
PPPs

Σ!

eltic-Plus
Smart Connected World

ITEA 2

ATRENE

National Programmes

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National Clusters

SYSTEMATIC
PARIS REGION SYSTEMS & ICT CLUSTER

BL Initiatives

GreenTouch™

BL Joint Research Labs or partnerships

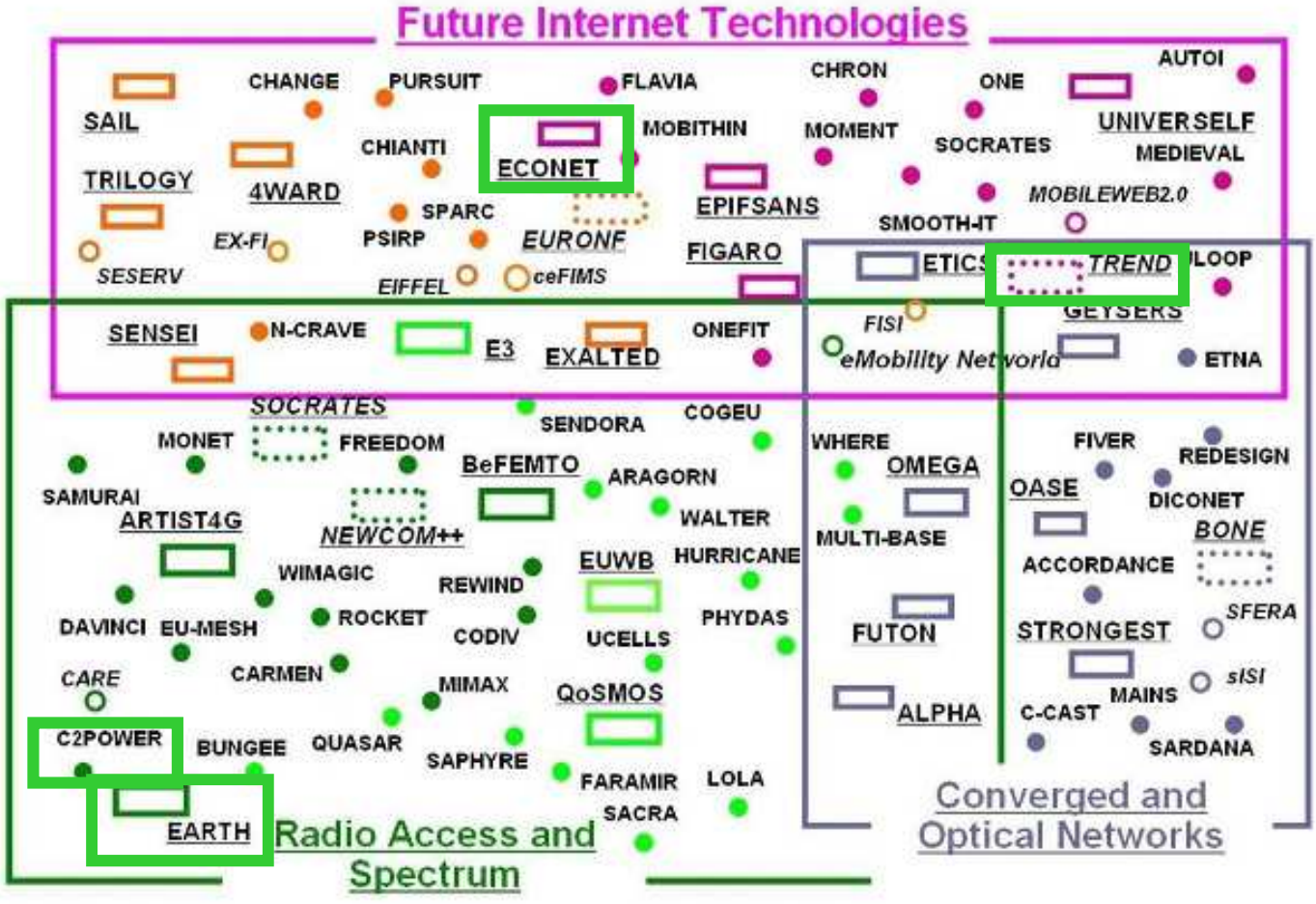
INRIA, iMinds…

Joint Customer Research

ALU BL EU Research Cooperations Framework (2/2)

EC D1/E1 Future Networks Projects – Energy Efficiency (Highlights)

EC E1 Call 4 & Call 5 Projects Portfolio and Clusters Organization

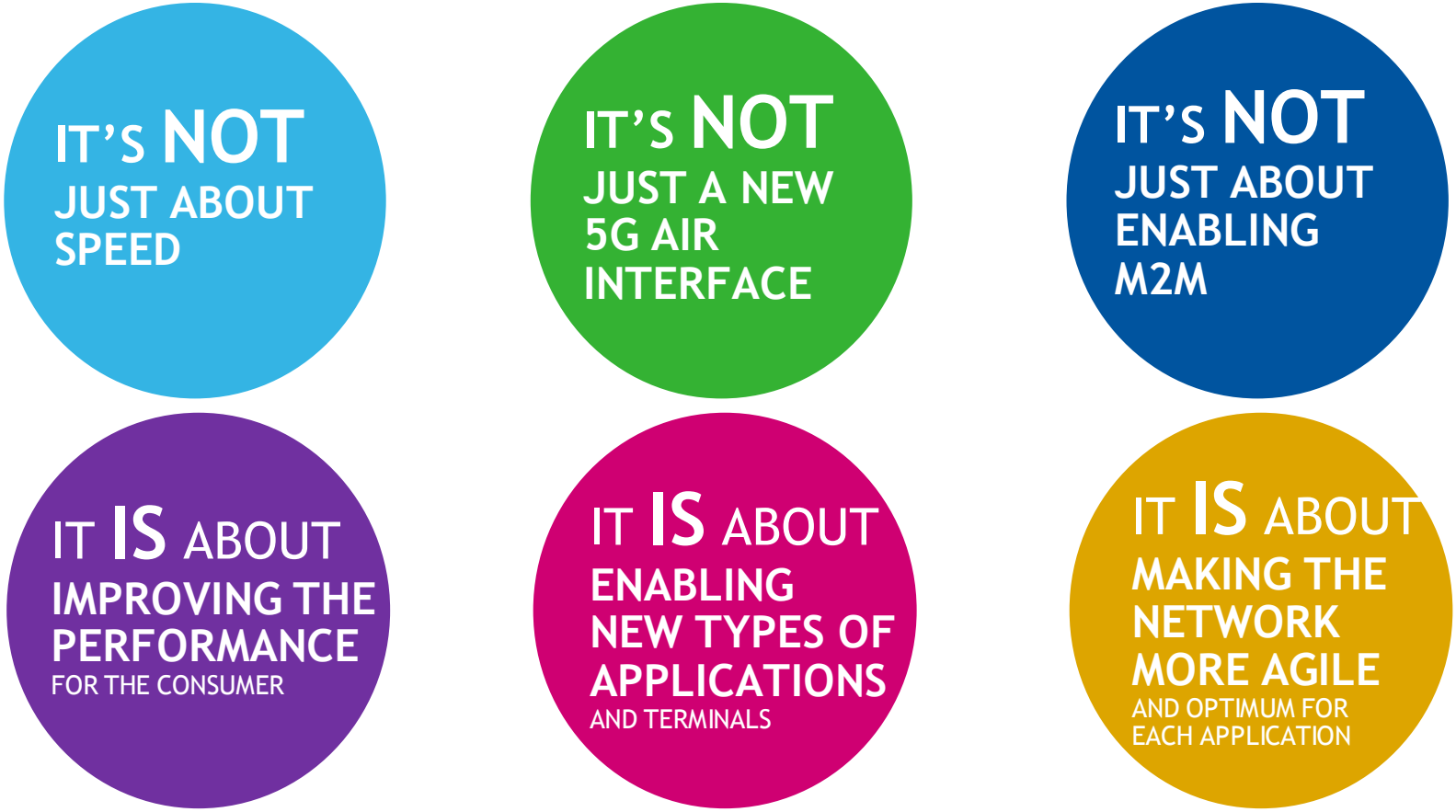


http://cordis.europa.eu/fp7/ict/future-networks/projects_en.html

5G ALU Perspectives (1/9)

What is 5G?

SO WHAT IS 5G?

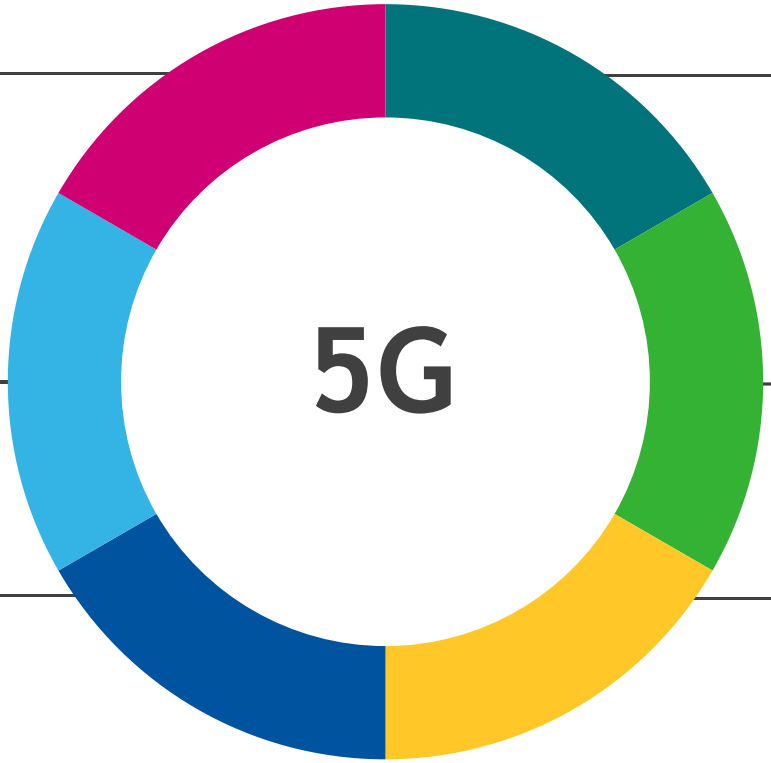


Alistair Urie – 5G Huddle Conference – 22-23.09.14 – London
https://eu-ems.com/summary.asp?event_id=219&page_id=1884

5G ALU Perspectives (2/9)

5G Dimensions

HOW WILL 5G IMPACT THE NETWORK OPERATOR'S BUSINESS?



BROADBAND
Massive traffic capacity
Reduce Cost
Spectrum efficiency
Access new spectrum

INNOVATIVE SERVICES
Flexible bearer design
3rd party policy

CROWD
Massive user density
User content
Correlated behavior

MISSION CRITICAL
Latency
Reliability
Availability
Security

BATTERY LIFE
Signaling reduction
Energy optimization

NON TRADITIONAL DEVICES
Short packet
Sporadic access
More devices
More device types

IT REQUIRES THAT THE REMAINING ISSUES WITH MOBILE NETWORKS BE SOLVED

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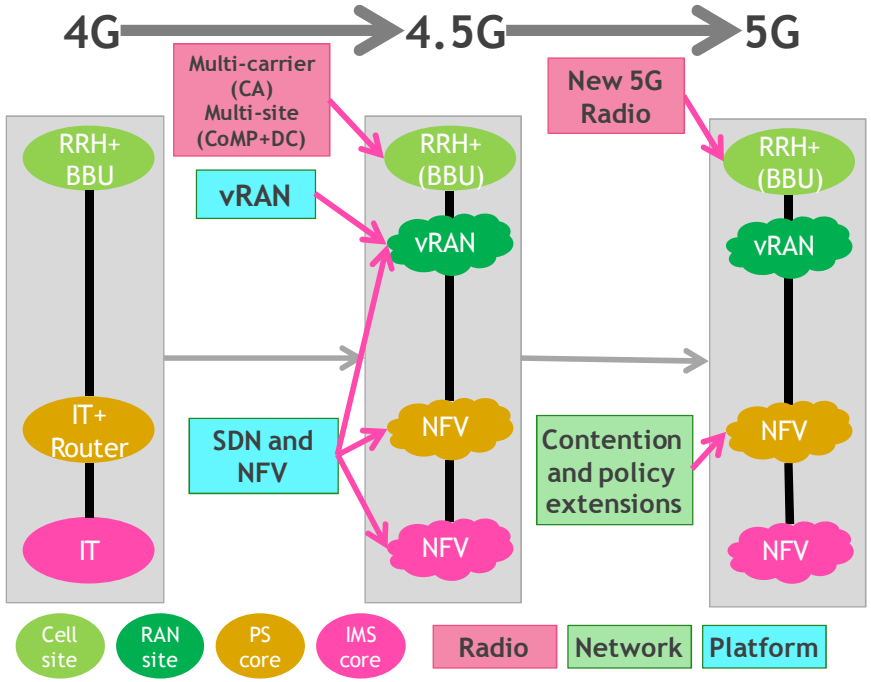
5G ALU Perspectives (3/9)
From 4G to 4.5G to 5G

WHAT WILL 5G LOOK LIKE?
BUILT ON THE FOUNDATION TECHNOLOGIES INTRODUCED BY 4.5G

- Radio features
  - Combining carriers: Carrier Aggregation:
  - Combining sites: Dual-Connectivity and CoMP
  - Combining cellular and WLAN: RAN based interworking
- Network features
  - Voice and multimedia with VoLTE and WebRTC
  - Combining cellular and WLAN: SaMOG/ePDG
  - Policy based networking: ANDSF and PCRF
- Platform features
  - Virtualizing cell site processing: vRAN
  - Virtualizing network: NFV and SDNs



4.5G HAS ALREADY STARTED AND IS LAYING DOWN THE FOUNDATION TECHNOLOGIES FOR 5G

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https://eu-ems.com/summary.asp?event_id=219&page_id=1884

5G ALU Perspectives (4/9)
KPIs and Design Targets

KPIS - WHICH ARE THE 5G DESIGN TARGETS?

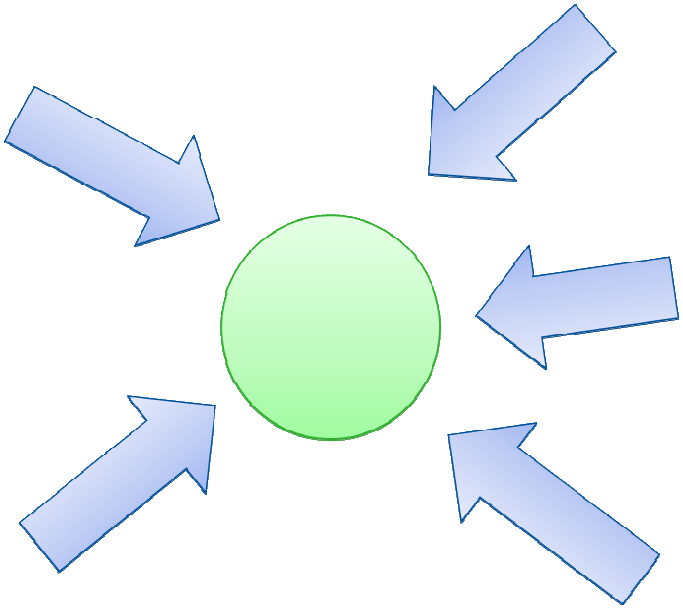
Diversity of services
- Video
- Internet
- Voice
- Small traffic

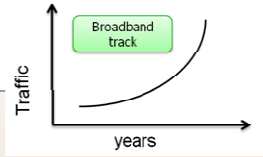
Service Options
- reduced latency
- Increased Link availability

Richer Service description
Rate description ((n)GBR ..), priority,
Latency information (Packet delay), oss rate **Low latency** option
Priority information (e.g. ARP) Availability class: best effort / prioritized
Mobility category: fixed / nomadic /vehicular
M2M characteristics (type class, periodicity, loss rate, sensor/actor)
UE power category
Security / Application privacy
Secured network (optional)
Reliability option

Security
- Privacy
- Security
- Availability

Public network
Secured sub-networks (PPDR ..)





Growth
Broadband & Internet:
Exponential growth (Factor X)

Number of devices (small traffic)

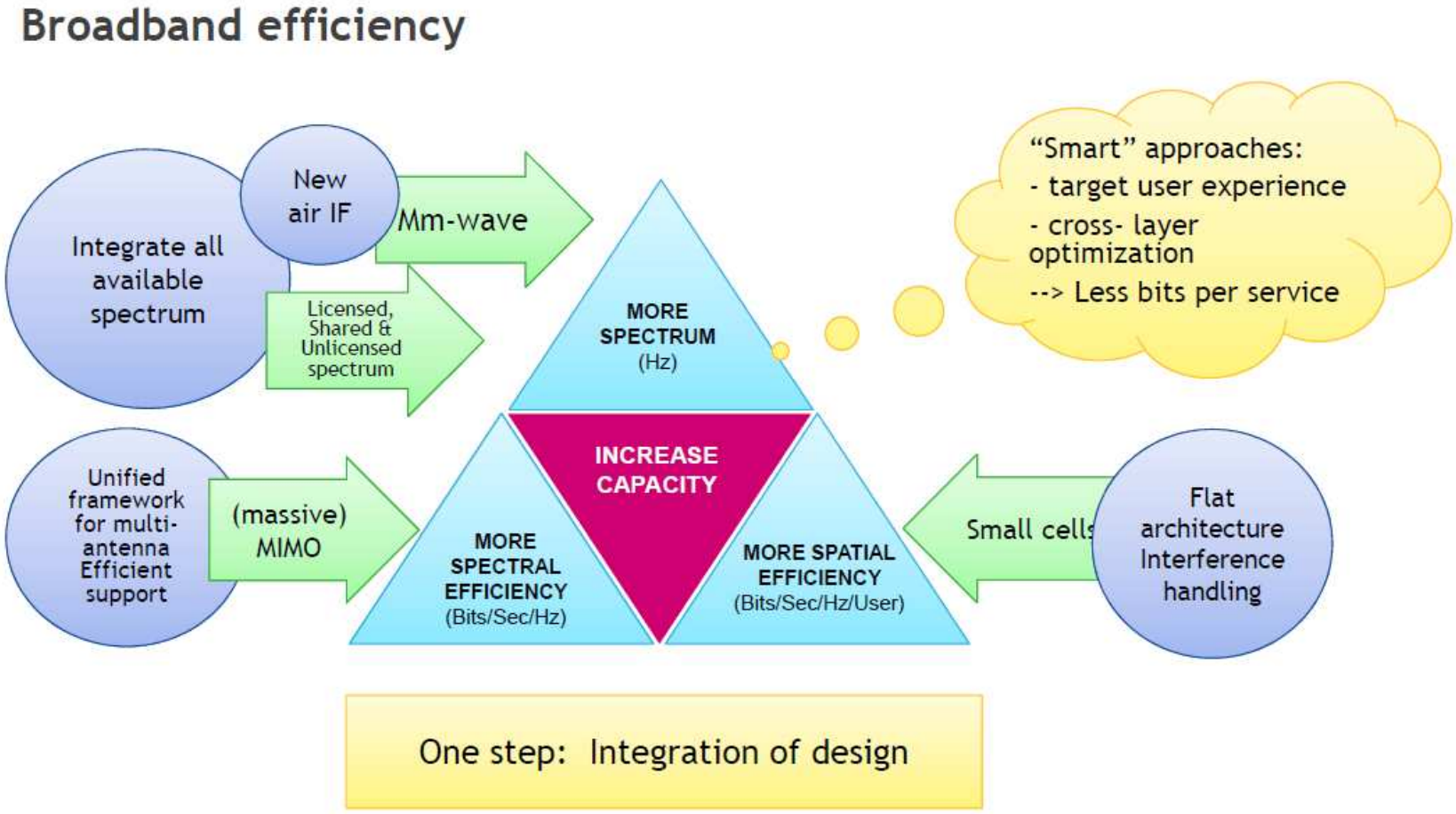
Cost
Sensitive areas (consumer):
- Indoor
- Urban internet
- Rural coverage

Efficiency
Spectrum efficiency
& efficient use of spectrum
Energy efficiency

Hans-Peter Mayer "H2020 Phases 2 and 3" – EC Consultation Workshop – 29.09.14 – Brussels
http://ec.europa.eu/digital-agenda/en/news/stakeholders-consultation-workshop-network-technologies-work-programme-2016-2017

5G ALU Perspectives (5/9)

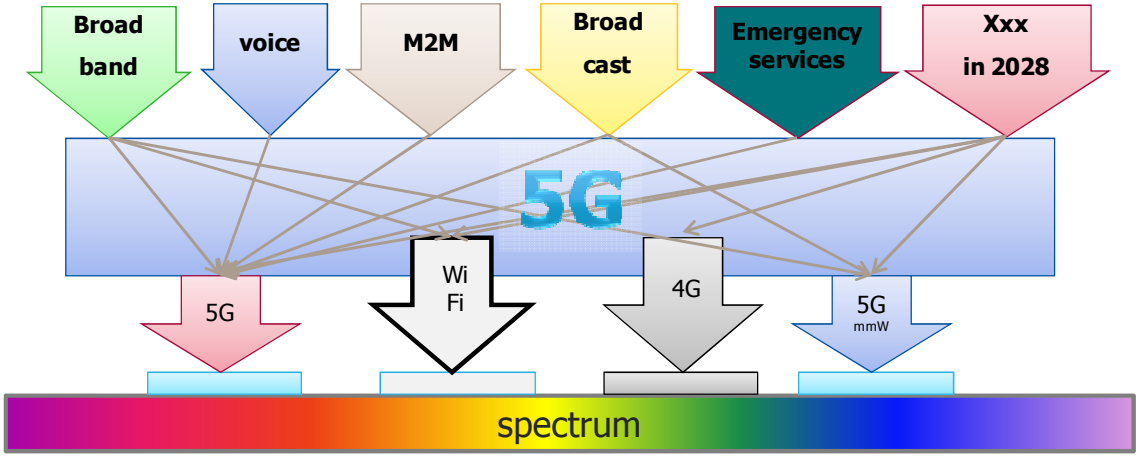
More Spectrum, Spectral Efficiency and Spatial Efficiency



Jean-Luc Beylat "5G: The Software Network and Virtualization Opportunities" – EuCNC 2014 – 25.06.14 – Bologna
http://www.eucnc.eu/2014/www.eucnc.eu/indexeb5c.html?q=node/106

5G ALU Perspectives (6/9)
Technologies and Spectrum

FROM MULTI-RAT TO FUSION OF RAT'S



heterogeneous services

Legacy RAT to be integrated: service mapping, handover ..

System sharing
instead of spectrum sharing

- Two levels of integration: 5G air interface and system: multi-RAT
- Sharing at system level: framework needed

Hans-Peter Mayer "H2020 Phases 2 and 3" – EC Consultation Workshop – 29.09.14 – Brussels
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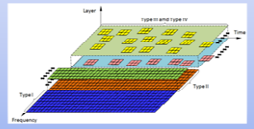
5G ALU Perspectives (7/9)
Core Technologies

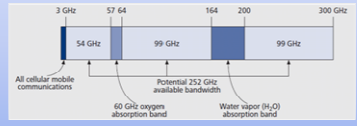
5G - CORE TECHNOLOGIES

Design for service

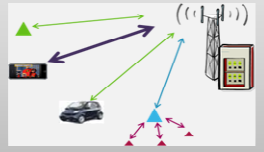
Multi-service air interface



Mm-wave point-to-multipoint access



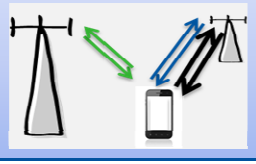
Small traffic



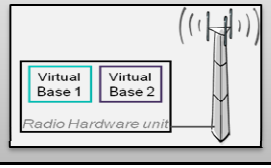
SIMPLIFICATION CONVERGENCE

- applications
- Network management
- control
- platform
- Transport
- RA Technologies
- Spectrum usage

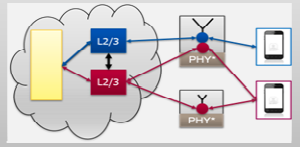
Native multipoint / multiantenna



SDN / virtualization Smart nodes



Service / user-centric network topology

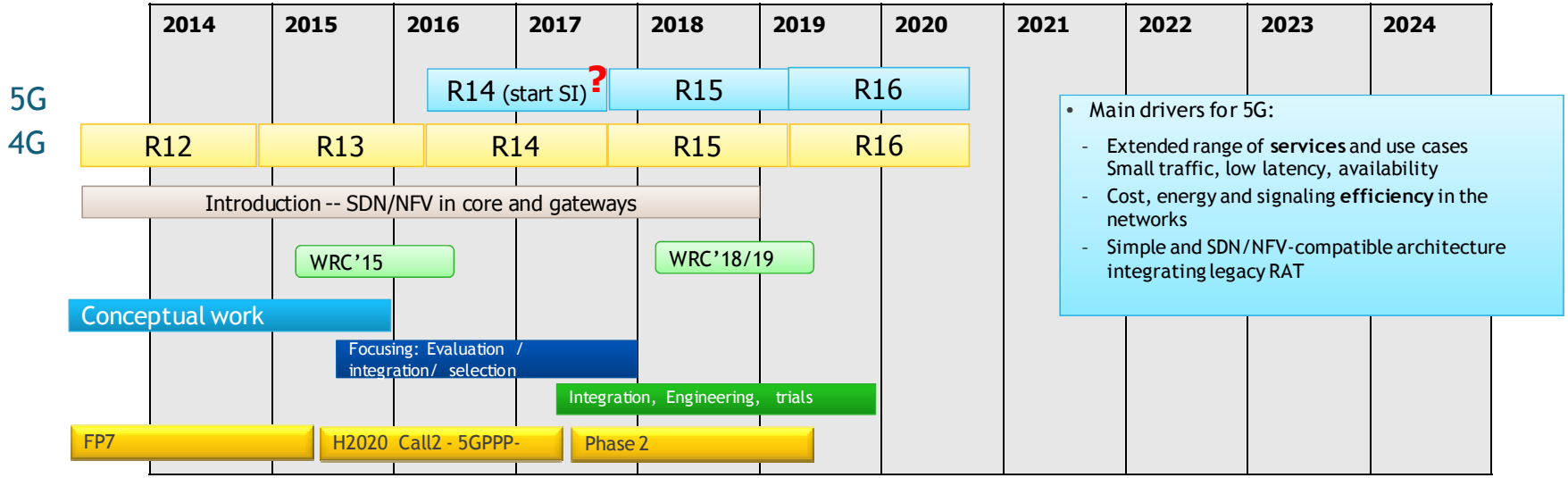


Hans-Peter Mayer "H2020 Phases 2 and 3" – EC Consultation Workshop – 29.09.14 – Brussels
http://ec.europa.eu/digital-agenda/en/news/stakeholders-consultation-workshop-network-technologies-work-programme-2016-2017

5G ALU Perspectives (8/9)

Standardization and 5G Infrastructure Phasing

EVOLUTION -- TRANSITION FROM LTE ++ TO 5G



- The focus of the projects should evolve with the maturing of the topics
  - Early phase: Conceptual work, scouting
  - Focusing phase: Quantitative evaluation, Assessment and selection of the technologies, integration of a system
  - Integration and Engineering phase
- Phasing : Number of people that can drive the process is limited. Phases should stay sequential.

Hans-Peter Mayer "H2020 Phases 2 and 3" – EC Consultation Workshop – 29.09.14 – Brussels
http://ec.europa.eu/digital-agenda/en/news/stakeholders-consultation-workshop-network-technologies-work-programme-2016-2017

5G ALU Perspectives (9/9)
Research Highlights

ONGOING BELL LABS RESEARCH

NEW 5G AIR INTERFACE

Support for short information packets - (M2M)

Continued improvement in sensitivity to extend range.

Improvements to increase both consumer battery life and energy consumption.

High frequency / millimeter-wave access technologies.

MOVE TO CLOUD

Move of most control/authentication functions to the Cloud.

Fully embrace use of SDN to provision optimum network to support traffic type.

Use of network function virtualization to provide dynamic provisioning and adaptation of the core support for different traffic types and user needs.

COMMUNICATIONS OPTIMIZATIONS

Full integration of multiple technologies (WiFi, Bluetooth, WCDMA, LTE, 5G) to provide a single communications solution.

Dynamic (<1s or shorter) pathway response to maintain a high consumer quality and experience.

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Tod Sizer "Beyond the 5G Hype" – ALU Technology Symposium 2013 – http://resources.alcatel-lucent.com/?cid=171016

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5G Infrastructure PPP in a Nutshell (1/5)

PPP Programme and KPIs

- PPP Programme that will deliver solutions, architectures, technologies and standards for the ubiquitous 5G communication infrastructures of the next decade
- Programme Ambitions: Key Challenges / High level KPIs
  - Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
  - Saving up to 90% of energy per service provided. The main focus will be in mobile communication networks where the dominating energy consumption comes from the radio access network
  - Reducing the average service creation time cycle from 90 hours to 90 minutes
  - Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
  - Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people
  - Enabling advanced User controlled privacy

Source: 5G PPP Annex to contractual arrangement

5G Infrastructure PPP in a Nutshell (2/5)

PPP Programme and Detailed KPIs (Contractual Agreement)

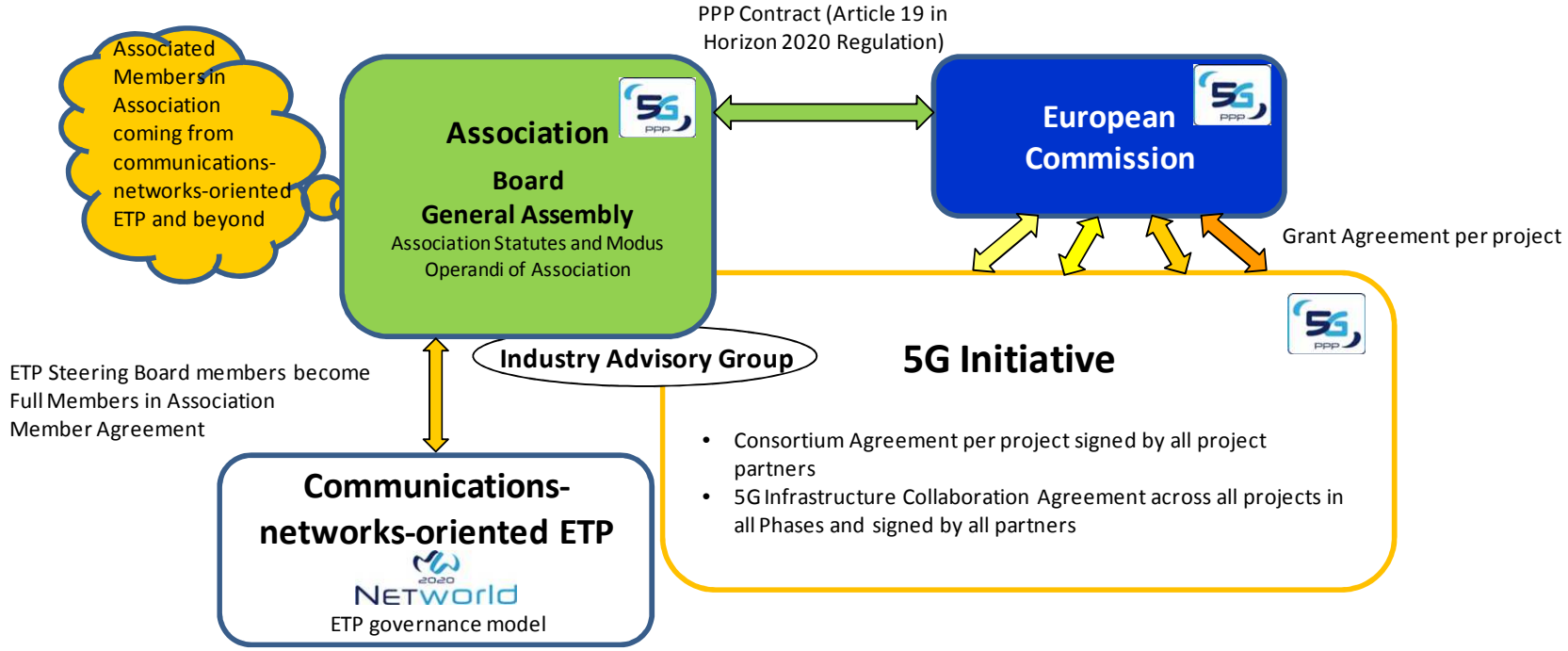
- Business-related KPIs
  - Leverage effect of EU research and innovation funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times
  - Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding
  - Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43 % global market share in communication infrastructure.
- Performance KPIs
  - Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010
  - Reducing the average service creation time cycle from 90 hours to 90 minutes (as compared to the equivalent time cycle in 2010)
  - Very dense deployments to connect over 7 trillion wireless devices serving over 7 billion people
  - Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision
- Societal KPIs
  - Enabling advanced User controlled privacy
  - Reduction of energy consumption per service up to 90 % (as compared to 2010)
  - European availability of a competitive industrial offer for 5G systems and technologies
  - New economically-viable services of high societal value like U-HDTV and M2M applications
  - Establishment and availability of 5G skills development curricula in partnership with the EIT

Source: 5G PPP Annex to contractual arrangement

5G Infrastructure PPP in a Nutshell (3/5)

PPP Gouvernance

- NetWorld 2020 will support the 5G PPP by
  - the direct relation to the PPP Association and
  - the development of the SRAI for the 5G-PPP



- The Association is an international non-profit association, named "The 5G Infrastructure Partnership" under Belgian law. It is the contractual counterpart of the European Commission for signing the 5G-PPP contract, done on 17 December 2013, see http://europa.eu/rapid/press-release_IP-13-1261_en.htm.

Source: New ETP and Annex to 5G Infrastructure PPP Contractual Arrangement

5G Infrastructure PPP in a Nutshell (4/5)

PPP Participation – ETP and Projects

- Participate in the Networld2020 ETP (http://networld2020.org/) and the 5G Infrastructure Association (http://5g-ppp.eu/) activities
  - Participation starts with ETP membership
  - Contribute to the Expert Group to update SRIA
  - Support requirements capturing on future networks
  - Members of ETP can be candidates for ETP Steering Board / Association and additional members in Association
- In 5G Infrastructure PPP projects
  - Commission is publishing Open Calls for Proposals
  - Everyone can submit proposals
  - Independent evaluators select proposals based on criteria (scientific and technological excellence, impact and Implementation)
  - Integration of successful proposals into the PPP program in order to ensure cooperation of projects
- There is no membership in 5G Infrastructure PPP, participation in PPP projects is open
- EC Call 1 - 5G Infrastructure PPP - H2020-ICT-2014-2 (DL on 25.11.14)
  - http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/77-ict-14-2014.html

Source: 5G Infrastructure Association

5G Infrastructure PPP in a Nutshell (5/5)

PPP Participation – Info Days, Brokerage and SMEs WG

- PPP session during Athens FIA on 20.03.14 in Athens
  - https://www.fi-athens.eu/program/sessions/5g-ppp-event (PPP slides)
- PPP Info Day on 28.04.14 in Issy Les Moulineaux (Orange)
  - http://5g-ppp.eu/5g-ppp-information-day-paris/ (PPP slides and 24 EoIs slides)
- PPP Info Day on 28.05.14 in Brussels (EC)
  - http://5g-ppp.eu/5g-ppp-awareness-meetinginformation-day-on-may-28-2014-in-brussels/ (PPP slides and 37 EoIs slides – 8 / 4 / 11 / 5 / 9)
- PPP FR Info Workshop on 17.06.14 in Paris
  - http://www.systematic-paris-region.org/fr/actualites/retour-sur-le-workshop-5g-ppp (PPP slides and 18 EoIs slides)
- PPP Workshop during EuCNC 2014 on 26.06.14 in Bologna
  - http://5g-ppp.eu/events/
- PPP Brokerage Platform set-up by the Association on the 5G PPP website
  - http://5g-ppp.eu/5g-ppp-brokerage-service/ - http://5g-ppp.eu/contacting-proposals
- NetWorld2020 SMEs WG
  - SME WG coordinated by Jacques Magen (InterInnov) and actively supported by Karl Schattauer (NetWorld2020 vice-Chair)

5G Infrastructure PPP Pre-structuring Model (1/7)

Pre-structuring Model Version 2.0 - Slide 2

- PPP is an ambitious Programme with ambitious KPIs
- More than a group of standalone projects working together through Concertation & Clusters meetings and activities
- Pre-structuring Model
  - Ensuring that the right set of projects will work together
  - Model focused on projects portfolio and related projects, not proposals as such
  - Possible set of projects objectives, scopes and expected impacts
  - Projects interfaces and possible cross-issues to be defined to reach the PPP KPIs
    - Example of Energy Efficiency to be seen as "by design"
  - Model focused on PPP Phase 1 as described in EC LEIT Work Programme 2014-2015 (ICT 14 – 2014: Advanced 5G Network Infrastructure for the Future Internet - http://ec.europa.eu/information_society/newsroom/cf/dae/document.cfm?doc_id=3958)
- Possibility to have proposals submitted according to the model ("guideline")?
- Possibility to then have EC reviewers making their best selection to fill one project with the best corresponding proposal ("guideline")?
- Avoiding duplication ("hype") and gaps issues?

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP Pre-structuring Model (2/7)

Pre-structuring Model Version 2.0 - Slide 3

- Model defined, communicated, enriched, endorsed before end of April 14
  - Approach initiated in 2013 (http://5g-ppp.eu/coverage-plans)
  - Pre-structuring Model Version 1.0 released publicly on 19.03.14 (http://5g-ppp.eu/wp-content/uploads/2014/03/March-2014-_5G-Infra-PPP_Pre-structuringModel_v1-0.pdf)
  - Open Consultation launched on 19.03.14 with deadline for contributions on 17.04.14 (http://5g-ppp.eu/consultation/)
  - 5G Infrastructure PPP session during FIA 2014 on 20.03.14 in Athens
  - More than 20 contributions received and processed to enrich the Model from Version 1.0 to Version 2.0
    - Note that the Model does not exclude particular technologies
  - Info Day on 28.04.14 in Issy Les Moulineaux (Orange)
  - Pre-structuring Model version 2.0 is the final version
- Additional documents from the 5G Infrastructure Association to contribute to the further definition of the PPP preparation will be communicated in the coming months
  - More details on last slide
- Next 5G Infrastructure PPP workshop during EuCNC 2014 (26.06.14 in Bologna)

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP Pre-structuring Model (3/7)

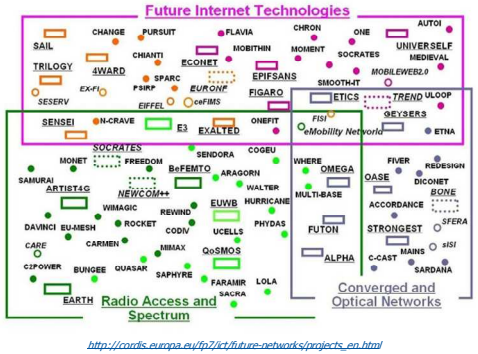
Pre-structuring Model Version 2.0 - Slide 4

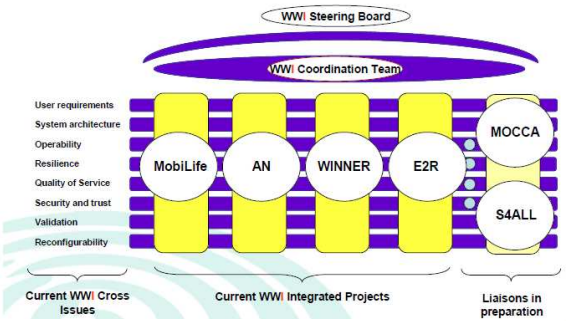
Projects Pre-definition & Specification

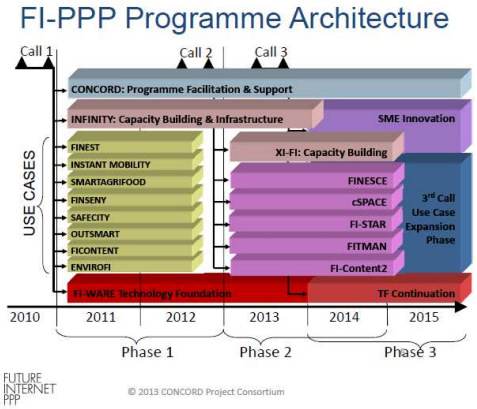
- Standalone Projects
- Potential connections between Proposals
- Clusters and Concertation
- Loose Coupling

- Coordination of set of proposals
- Tight connections between proposals
- Clusters and Concertation for projects outside of the initiative
- Joint events / meetings based on WWI momentum
- No joint technical KPI

- Very tight pre-definition and integration







FP6-like
FP7-like

FP6 WWI

FI PPP

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

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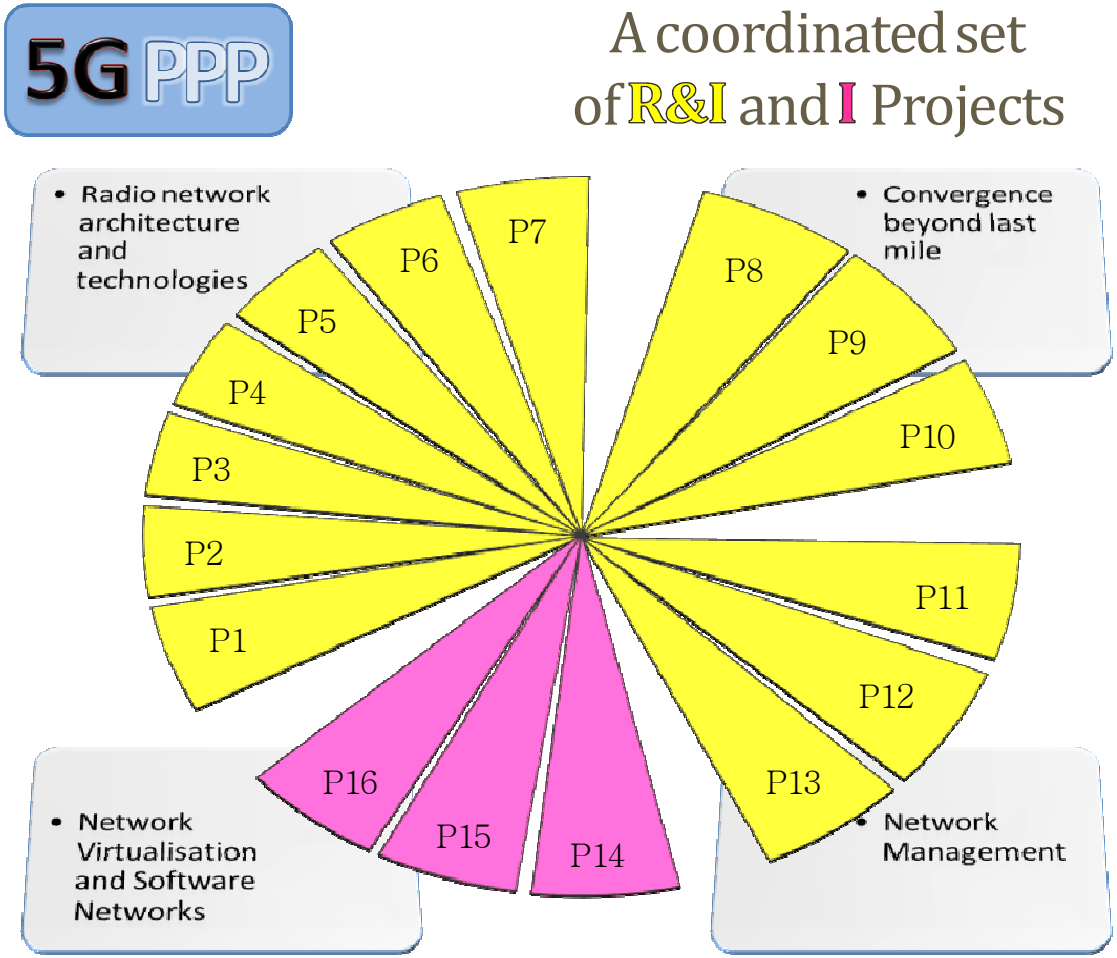
5G Infrastructure PPP Pre-structuring Model (4/7)

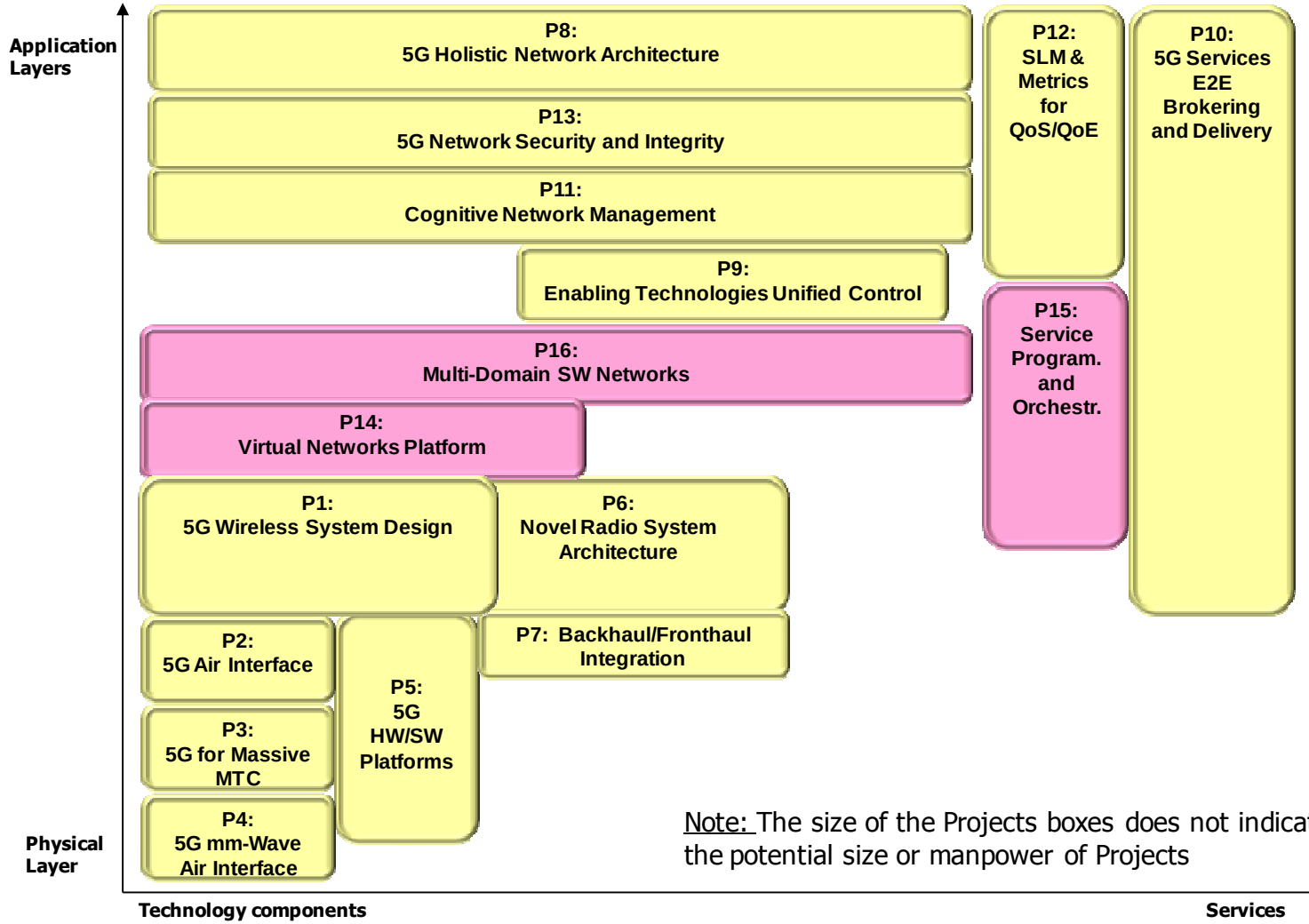
Pre-structuring Model Version 2.0 - Slide 6



http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP Pre-structuring Model (5/7)

Pre-structuring Model Version 2.0 - Slide 8



Note: The size of the Projects boxes does not indicate the potential size or manpower of Projects

8

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP Pre-structuring Model (6/7)

Pre-structuring Model Version 2.0 - Slide 10

P2: Air Interface and Multi-Antenna, Multi-Service Air Interface below xx GHz

Objective

- To design a highly flexible and adaptable air interface being able to support efficiently
  - the multitude of service classes (from continuous high rate to sporadic low rate and with an option for very low latency) and service types (bi-directional unicast, uni-directional broadcast / multicast)
  - and device types (from high-end tablet to low-end device, incl. Body Area Devices)
  - and MIMO capabilities (in both UE and eNB)
  - in various areal settings (from heterogeneous ultra dense urban setting with cooperation to macro cell dominated rural/remote –land, sea and air areas)
  - with flexible spectrum usage

Scope

- **Scalability, adaptability, flexibility** - to meet temporal and areal fluctuations of active service and device class mixes and to support massive simultaneous network access
- **Energy efficiency** - both for the radio access network and devices
- **Uniform coverage, high capacity** – interference-robustness, adaptability to a wide range of spectrum allocations, high spectral efficiency at minimal control overhead
- **Unified multi-antenna support** - support localized, distributed and co-ordinated multi-antenna systems as an embedded feature in a natural way, and channel models
- **Robustness** – to support very high velocity (high-speed trains and other environments, access and backhaul) and relaxed synchronisation (low-end devices)

Expected Impact

- Enable 5G to support both broadband and machine type transmissions within the same band with high efficiency and at similar costs (devices and energy) compared to dedicated solutions
- Expand the business model and broaden the market of providing wireless services
- Easy implementation under various settings (deployment, carrier frequency …)
- Increased and uniform quality of experience
- Contribution to standardisation bodies

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP Pre-structuring Model (7/7)

Pre-structuring Model Version 2.0 - Slide 25

- Pre-structuring Model version 2.0 will be the final version
- Additional documents from the 5G Infrastructure Association to contribute to the further definition of the PPP preparation will be communicated in the coming months
  - Definition of potential Projects cooperation (e.g. Projects interfaces and Cross Issues)
  - Further definition of PPP KPIs
  - Definition of possible CSA(s) organization and operation to support the PPP
  - Definition of possible common scenarios and use-cases to be considered by the PPP Projects (in connection with the ETP White Papers and forthcoming ETPs and Association Workshops)
  - Further definition of Association milestones and priorities for Phase 1
- Next 5G Infrastructure PPP workshop during EuCNC 2014 (26.06.14 in Bologna)

➡ Stay tuned and join us in implementing a very successful PPP with impact!

http://5g-ppp.eu/wp-content/uploads/2014/03/5G-Infra-PPP_Pre-structuring-Model_v2.0.pdf

5G Infrastructure PPP EE 90% KPI (1/11)

Key Programmatic Issues / Questions (Highlights)

- Detailed definition and understanding of the Programme KPI
  - Saving up to 90% of energy per service provided / Reduction of energy consumption per service up to 90 % (as compared to 2010)
- Definition of the reference values incl. traffic growth assessment
- Definition of the system model, methodology (E2E) and metrics
- Assessment of the performance of Projects solutions
  - EE benefits of architectures, technologies, components, devices, algorithms and protocols
- Assessment of the Program performance combining Projects solutions
- Monitoring of the KPI over Programme Phases
- Definition of the potential orientations for Projects technical solutions based on KPI prioritization
- Definition of the potential orientations for the follow-up Phase priorities based on KPI prioritization

5G Infrastructure PPP EE 90% KPI (2/11)

Benefiting from FP7 Experience (Highlights)

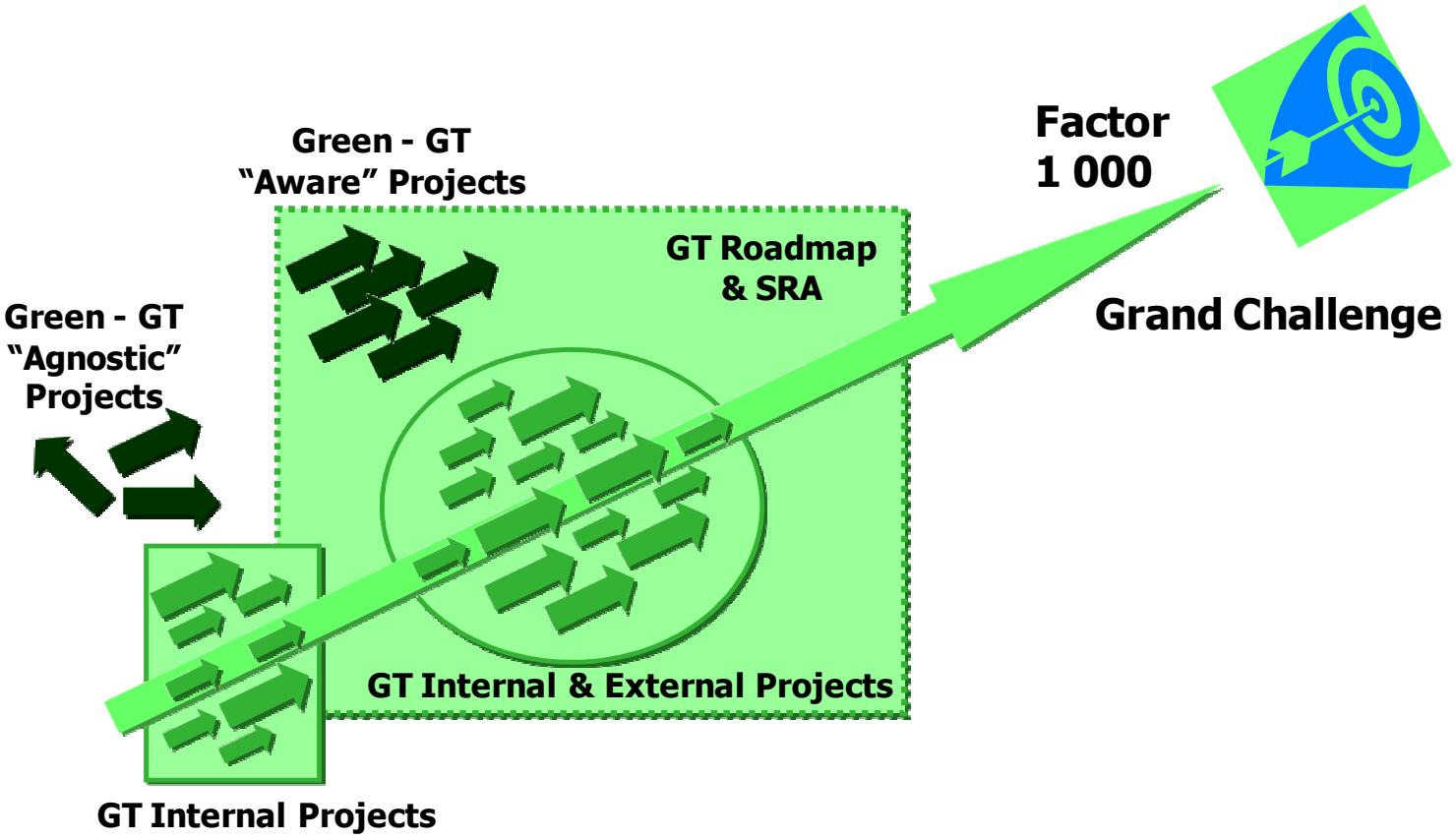
- EC FP7 EARTH, TREND, ECONET, C2POWER Projects, deliverables, events…
- Green ICT TREND & GT Workshop on 19.04.13 in Torino
- Dublin FIA session « Green ICT: What would be the cost of doing nothing? » on 09.05.13 in Dublin
- EC E1 FI Cluster Workshop on Green ICT on 22.10.13 in Brussels

http://www.fi-dublin.eu/green-ict/

5G Infrastructure PPP EE 90% KPI (3/11)

Grand Challenge and GreenTouch Initiative

GreenTouch™ Cooperations - Grand Challenge



Didier Bourse – EC E1 Concertation Meeting – 11.10.12 – Brussels

http://cordis.europa.eu/fp7/ict/future-networks/concertation-clusters_en.html

5G Infrastructure PPP EE 90% KPI (4/11)

GreenTouch Initiative

http://www.greentouch.org/

5G Infrastructure PPP EE 90% KPI (5/11)

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Global Study by Greentouch Consortium Reveals How Communications Networks Could Reduce Energy Consumption by 90 Percent by 2020

In May 2013, GreenTouch announced findings of its Green Meter research study, a first-of-its kind analysis that provides the industry with a better understanding of energy efficiencies possible in network operations in 2020. The analysis indicates that net energy consumption in networks can be reduced significantly—up to 90 percent—by 2020. The study takes into account new technologies, architectures and protocols, as well as the dramatic increases anticipated in communications traffic over the next decade.

Key findings include:

- Mobile networks stand to benefit the most from energy-efficiency efforts, as they are the most inefficient and yet the fastest growing networks in terms of data volumes.
- Mobile networks could realize potential energy efficiency improvements of up to 1043 times.
- Energy efficiencies in fixed-line and core networks are also expected, but will be less dramatic. The modeling shows potential improvements in fixed access networks of 449 times and improvements in the core network of 64 times. Such networks are already relatively energy-efficient, so further gains will be less significant and much harder to achieve than with mobile networks.

Models encompassed a combination of forecasting and trend projections, theoretical and analytical calculations, semi-analytical optimizations and network simulation, and focused on determining potential energy-efficiency improvements as well as energy reductions.

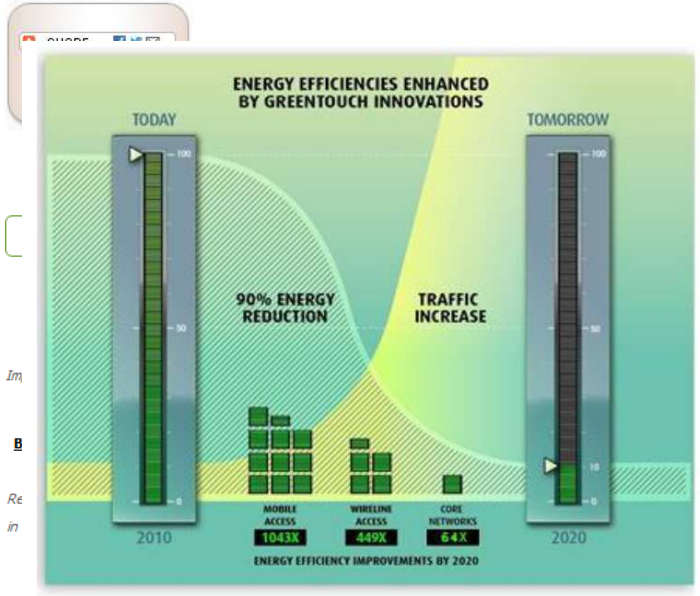


Figure 1: Energy efficiencies enhanced by GreenTouch innovations.

http://www.greentouch.org/index.php?page=green-meter-research

5G Infrastructure PPP EE 90% KPI (6/11)
GWATT

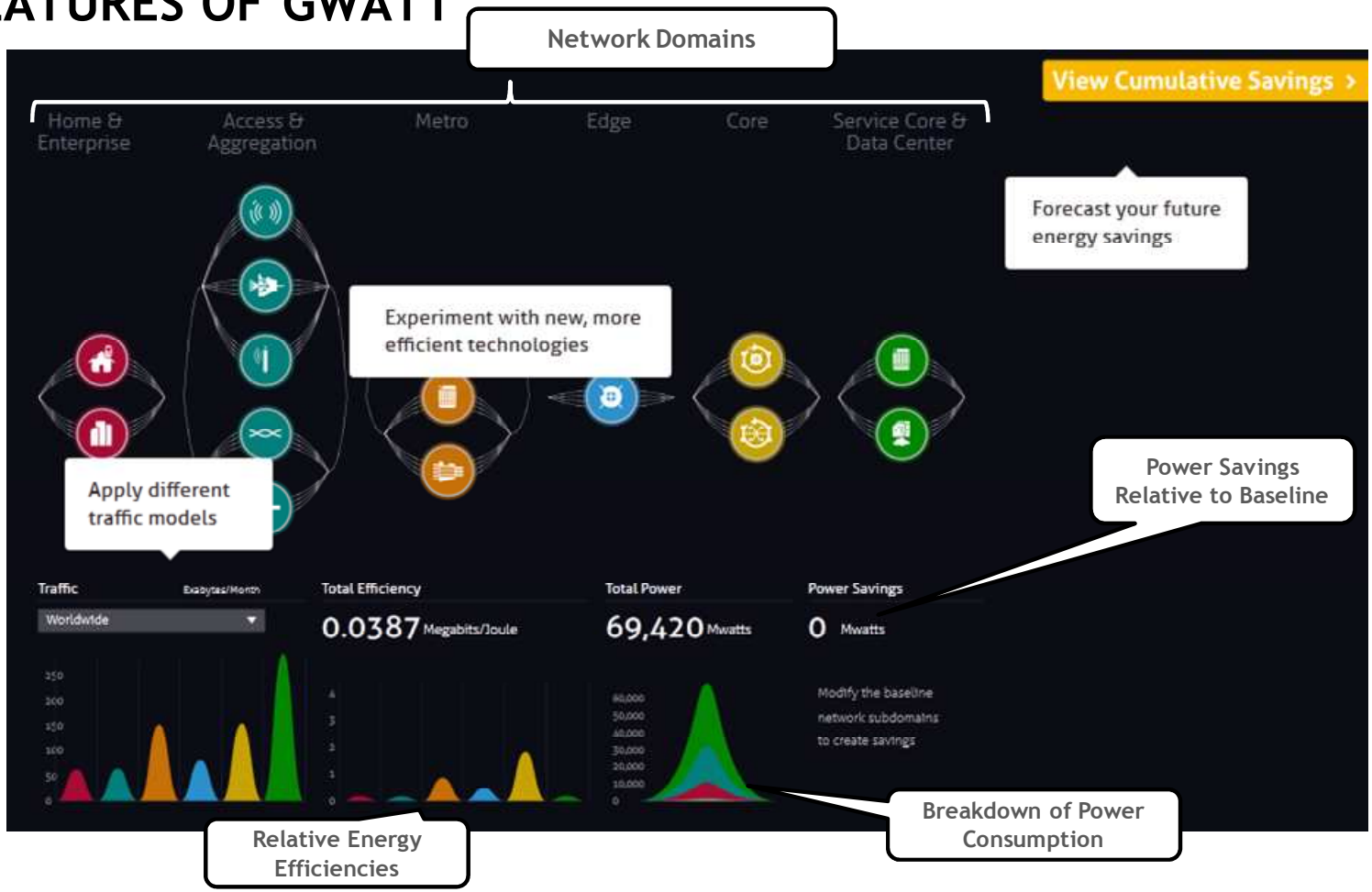
WHAT IS GWATT?

- An interactive application to measure the impact of new technologies on network energy consumption
- Identifies network hotspots and validates impact of >10x targeted improvements in energy efficiency
- Intended for network operators, architects, engineers and decision makers
- Forecasts trends in energy cost, consumption and carbon footprint
- Explores the relative impact of the latest technology evolutions
- Based on network modeling from Bell Labs and CTO and independent consortia like GreenTouch and GeSI

http://gwatt.net/

5G Infrastructure PPP EE 90% KPI (7/11)
GWATT

KEY FEATURES OF GWATT



http://gwatt.net/

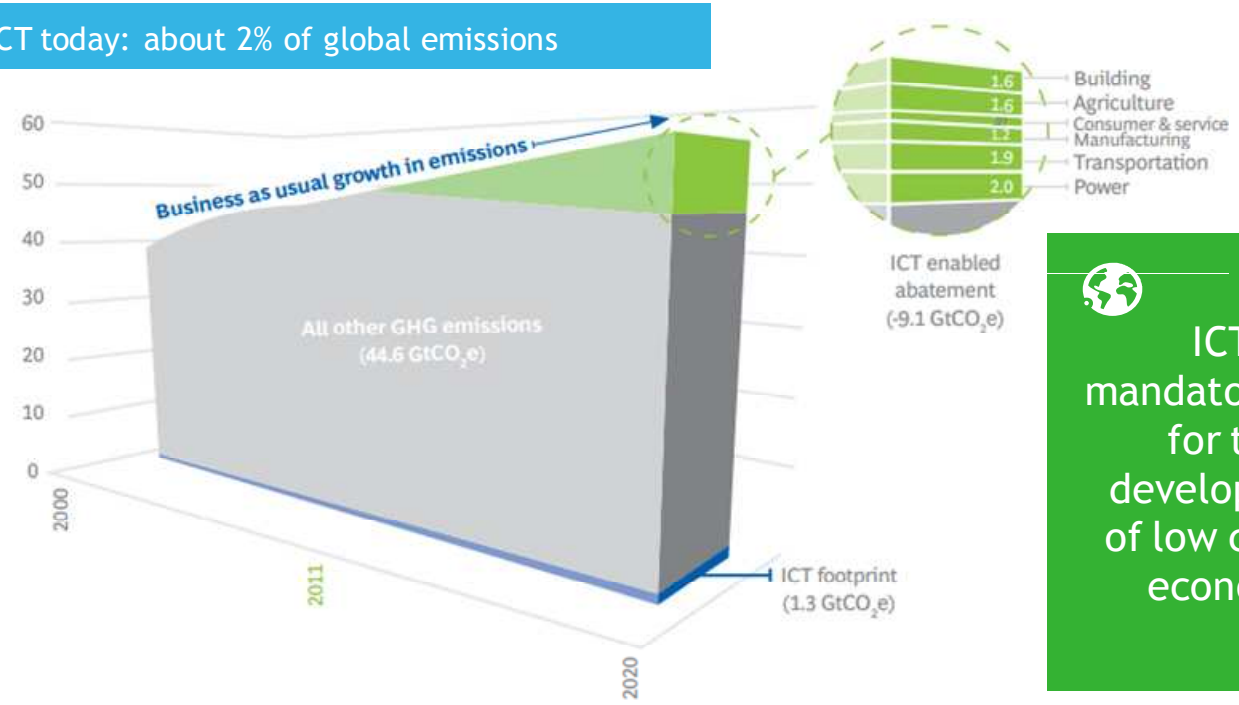
5G Infrastructure PPP EE 90% KPI (8/11)

The Enabling Effect

ICT IMPACT
THE ENABLING EFFECT

ICT can enable a 16.5% reduction in global GHG emissions by 2020

ICT today: about 2% of global emissions



ICT: mandatory path for the development of low carbon economy

Source: IEA, BCG analysis for GeSI SMARTer 2020: The Role of ICT in Driving a Sustainable Future

Philippe Richard - "ICT, we need more of it for less energy" – Dublin FIA – Green ICT Session – 09.05.13 – Dublin
http://www.fi-dublin.eu/green-ict/

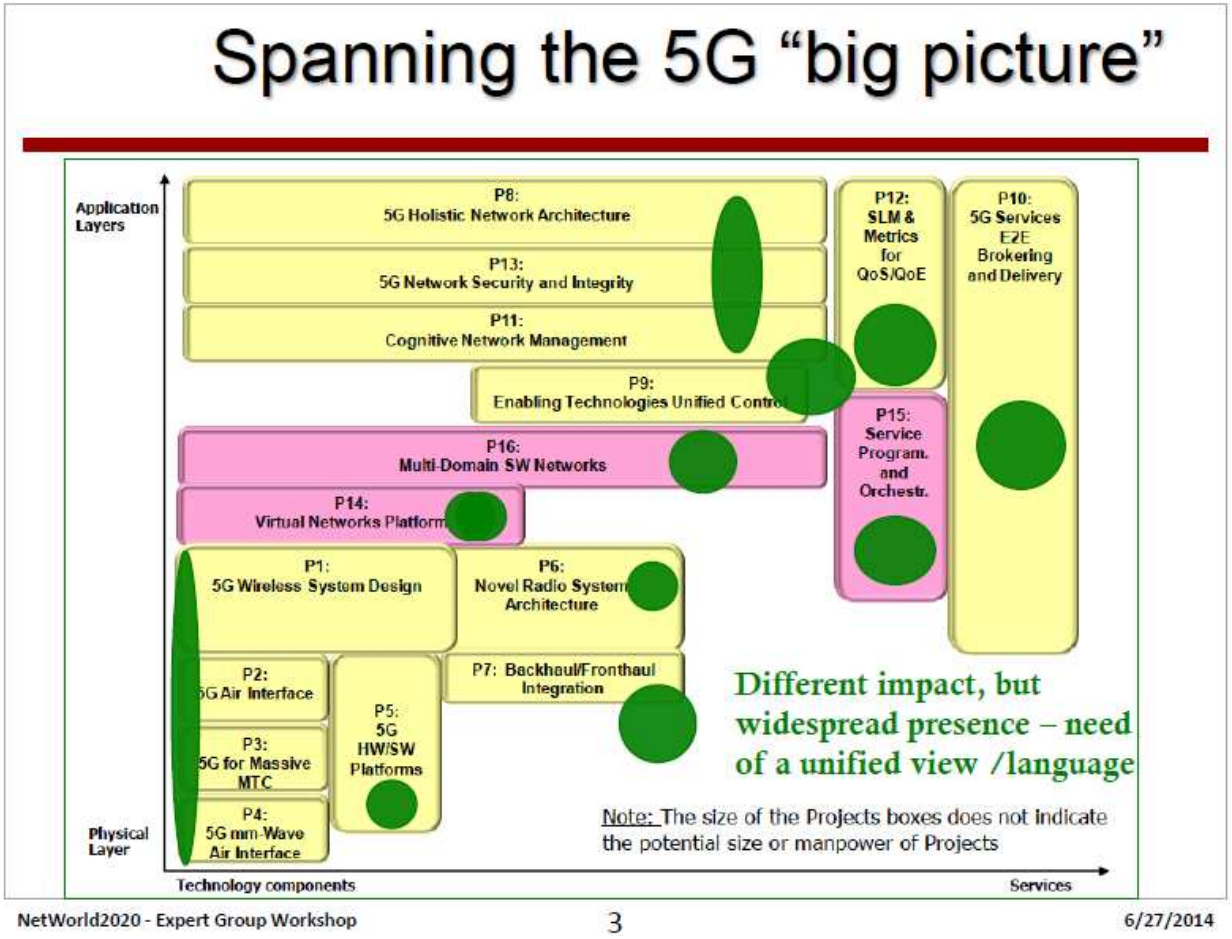
5G Infrastructure PPP EE 90% KPI (9/11)

KPIs and Cross-Issues (Pre-structuring Model Reference)

	WIRELESS							CONVERGENCE			NETWORK MANAGEMENT			VRTN & SN		
	RTD							RTD			RTD			INNO		
PPP KPIs / RTD & INNO PROJECTS	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**	**P13**	**P14**	**P15**	**P16**
Performance KPIs																
Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010																
Reducing the average service creation time cycle from 90 hours to 90 minutes (as compared to the equivalent time cycle in 2010)																
Very dense deployments to connect over 7 trillion wireless devices serving over 7 billion people																
Secure, reliable and dependable Internet with a "zero perceived" downtime for services provision																
Societal KPIs																
Enabling advanced User controlled privacy																
Reduction of energy consumption per service up to 90 % (as compared to 2010)																
European availability of a competitive industrial offer for 5G systems and technologies																
New economically-viable services of high societal value like U-HDTV and M2M applications																
Establishment and availability of 5G skills development curricula in partnership with the EIT																
Business-related KPIs																
Leverage effect of EU research and innovation funding in terms of private investment in R&D for 5G systems in the order of 5 to 10 times																
Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding																
Reach a global market share for 5G equipment & services delivered by European headquartered ICT companies at, or above, the reported 2011 level of 43% global market share in communication infrastructure																

5G Infrastructure PPP EE 90% KPI (10/11)

EE in the Pre-structuring Model



Franco Davoli - "Energy efficiency as a horizontal theme in 5G - The need for coordination and support"
EuCNC 2014 - NetWorld2020 Experts Group Workshop – 23.06.14 – Bologna
http://networld2020.eu/expert-advisory-group-workshop-bologna-23-june-2014/

5G Infrastructure PPP EE 90% KPI (11/11)

NetWorld2020 Joint White Paper – EC WP2016-17 Inputs

- **Energy efficiency**: Wireless/mobile broadband infrastructures account for more than 50% of the energy consumption of telecommunication operator networks, while the amount of global energy consumption of ICT approaches 4.5% with a rising trend[4]. It is important that future 5G networks meet requirements and challenges in an energy efficient manner (by achieving 90% of energy efficiency compared to 2010 levels, leading to the needed reduction of energy consumption in the light of the expected overall increase of ICT energy usage).

(Page 12)

3.2.3.5 Energy Efficiency

Energy efficiency of mobile networks has for long not been a dedicated research or design topic, yet efficiency has continuously improved. This has been driven by hardware gains due to Moore's Law and better utilisation of high SNR channels (modulation close to Shannon's limit). Further, smartphones and data flat rates have driven the utilisation of services, so that systems are more and more operating in a heavily loaded mode than in a coverage limited deployment with high energy consumption for little traffic. In these circumstances, a 1000x improvement of energy efficiency within the next 5 years is targeted. However, both of these drivers for energy efficiency are more or less exhausted. The expected further growth of data subscriptions, data rates and data volumes threatens to drive up energy consumption, deployment cost and operation cost of mobile networks. A new 5G system concept needs to drastically reduce the energy consumption per Mbit. All aspects of a mobile communication system need to be studied and improved for higher energy efficiency:

(Page 29)

- hardware efficiency (especially in new bands in the 30-90GHz range),
- waste reduction (coordinated transmission, beamforming and massive MIMO),
- new radio waveforms with less control overhead,
- deployments with shorter transmission ranges (ultra-small cells, D2D),
- faster transition from idle to connected mode (connection-less transmission),
- control overlay separate from data services,
- dynamic network management (load adaptive and context aware activation of additional resources),
- task offloading to centralized and more efficiently managed resources, and
- service provisioning (content caching, multicasting, opportunistic transmission).

NetWorld2020 Joint White Paper "5G: Challenges, Research Priorities, and Recommendations"
http://networld2020.eu/wp-content/uploads/2014/02/NetWorld2020_Joint-Whitepaper-V8_public-consultation.pdf

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