Innovation In Wireless

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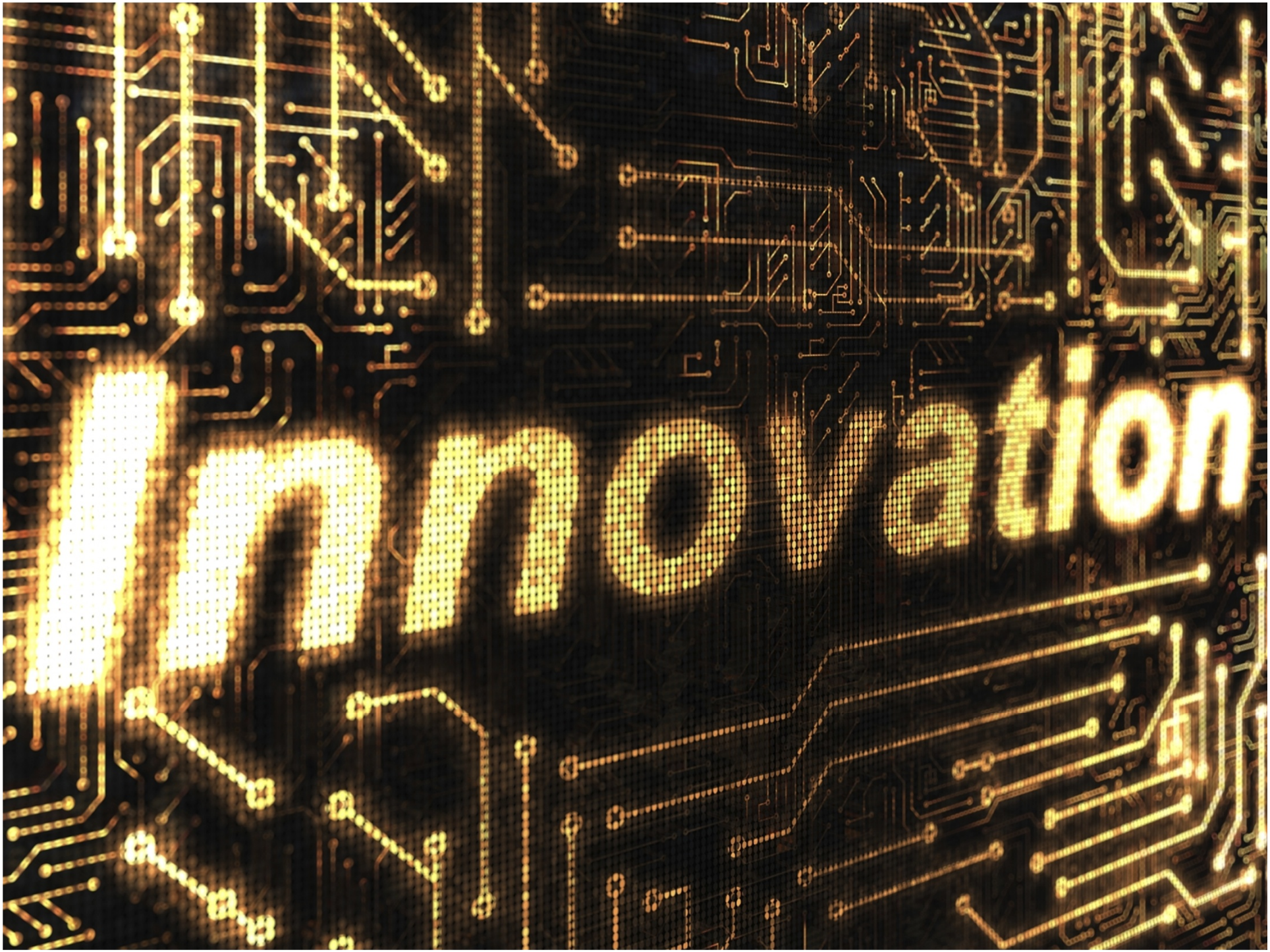

Innovation

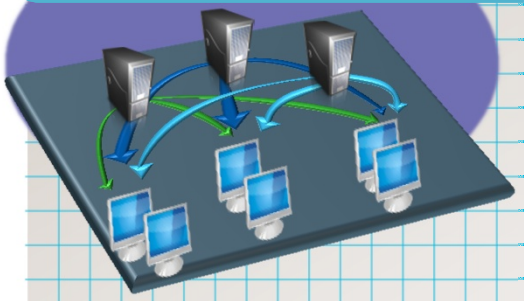
Challenges

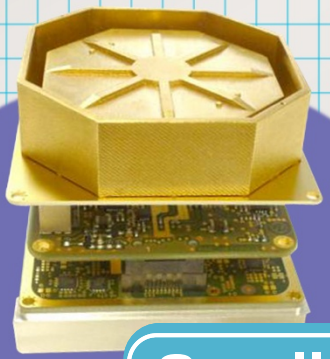
Opportunities for True Innovation

Trends

Mastering the Challenges

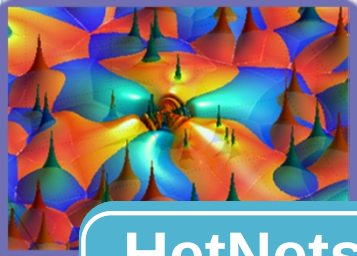
Smart Networks





Small Cells

HetNets



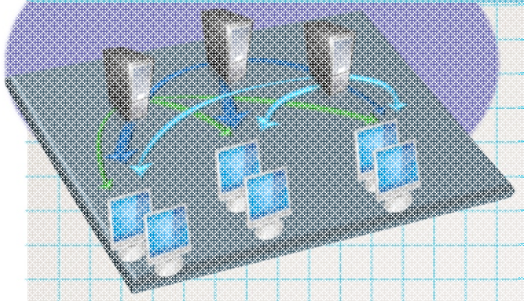
Service Awareness

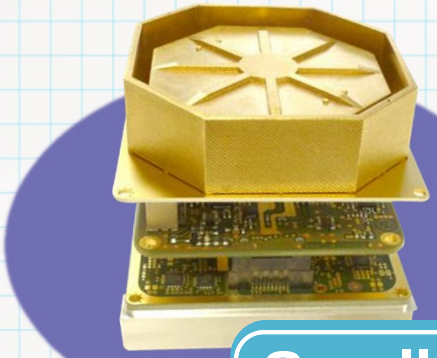
Cloud Processing

Trends

Mastering the Challenges

Smart Networks





Small Cells

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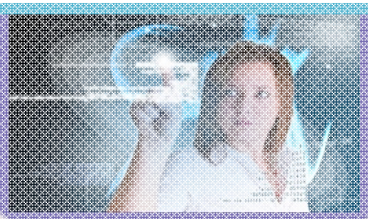
Service Awareness



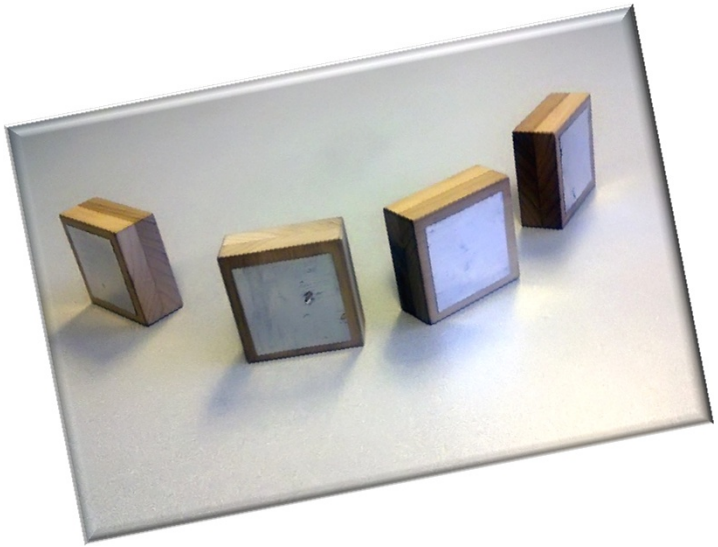
Cloud Processing

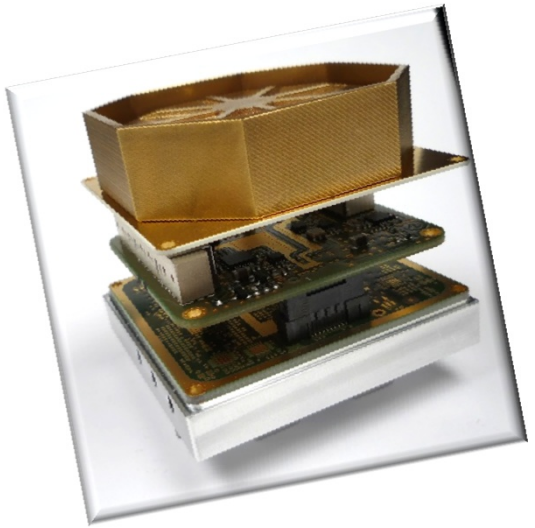
Is There A Better Way?

Small Cells to the Rescue

lightRadio™ Cube

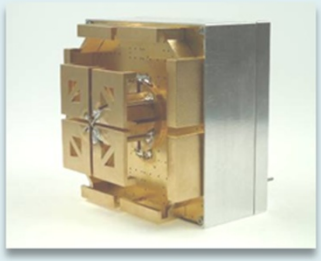
From Wooden Block to Reality





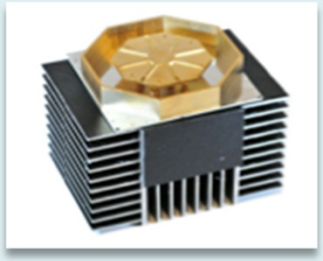
The (R)Evolution Continues

New Cubes



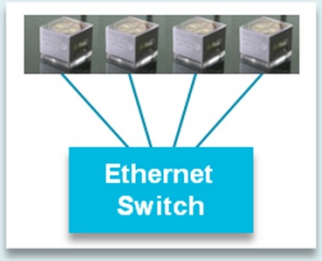
Dual Band Cube

- Use same footprint, power, and backhaul to support two bands.
- Ideal for 3G AND 4G together.
- Solution for 2.1 GHz and 2.6GHz simultaneously



High Power Cube

- New thermal management solutions allow for high power.
- High power allows for coverage of larger areas as well as a component in macrocellular arrays.
- New Doherty amplification techniques are employed with end stage efficiencies in excess of 50%.



Cabled Cube

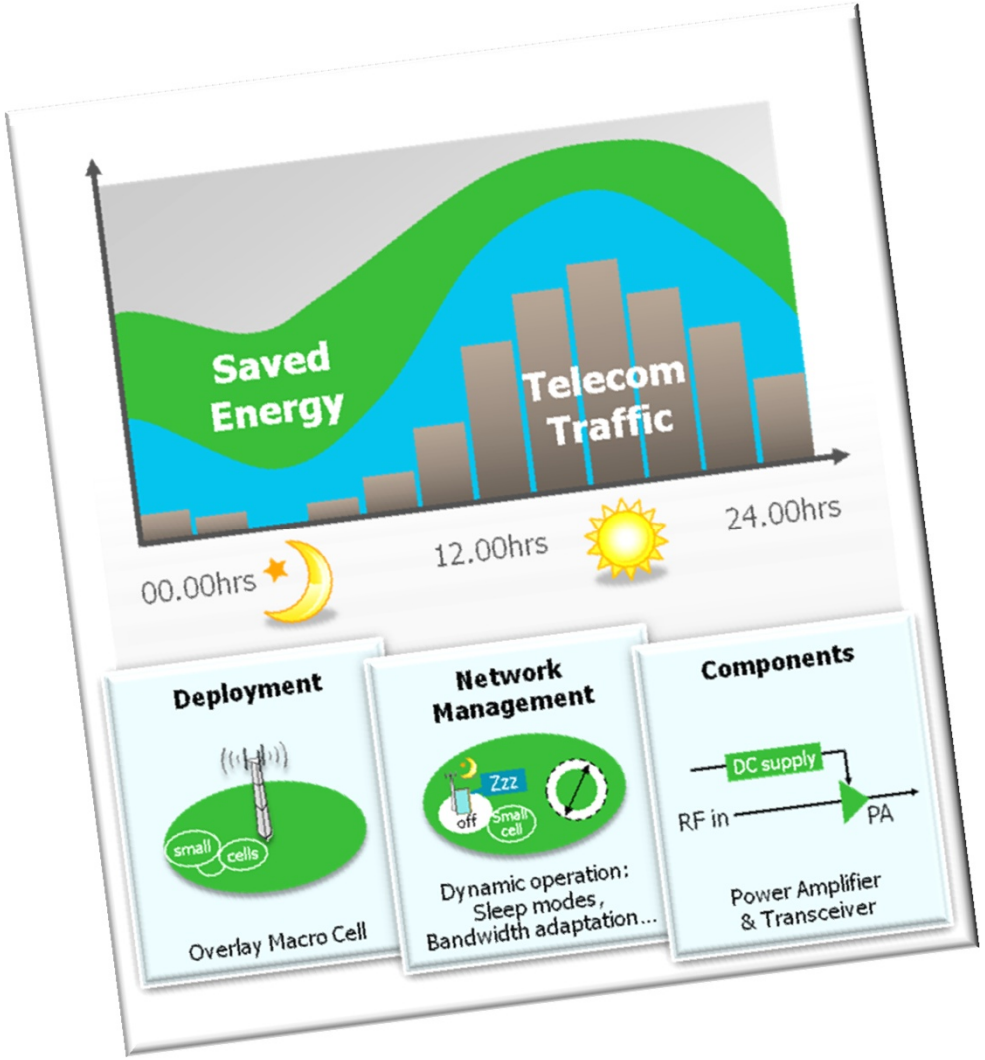
- Ethernet or CPRI cabled solution (optical or copper) allows great flexibility.
- Ideal for indoor deployments.
- Power over Ethernet can drastically reduce installation costs.
- Cabled flexibility offers new arrangements of cubes into unique arrays.

Shared Cube

- Proliferation of small cells outdoors as well as indoors will be expensive to provision.
- For many locations (esp. indoors) it may be expedient to share installation and infrastructure
- Wideband cube covers four bands/providers between 700MHz and 2.7GHz
- Backhaul to the baseband unit is over high speed CPRI (CPRI7, 9.8 Gb/s) or 10 gigabit ethernet (fiber or copper).

Improving Energy Efficiency

Small Cells – A Piece in the Puzzle



GreenTouch Consortium

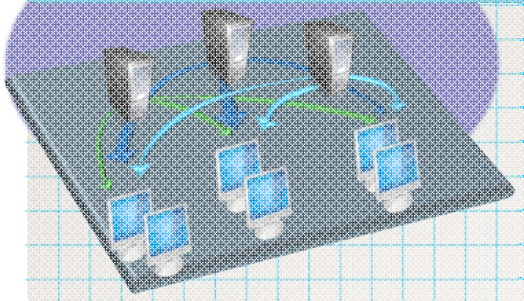
Increasing Network Efficiency by a Factor of 1000

- Global research consortium representing industry, government, and academic organizations
- Launched in May 2010
- 55 member organization
- 300 individual participants from 19 countries
- 25+ projects across wireless, wireline, routing, networking and optical transmission
- http://www.greentouch.org/

Trends

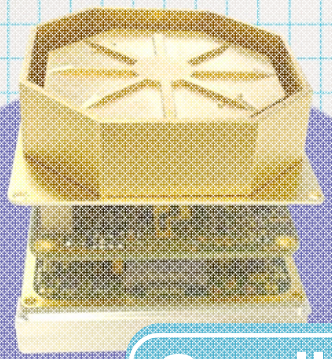
Mastering the Challenges

Smart Networks

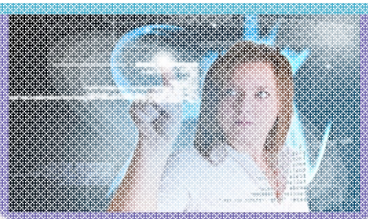


HetNets

Small Cells



Service Awareness



Cloud Processing

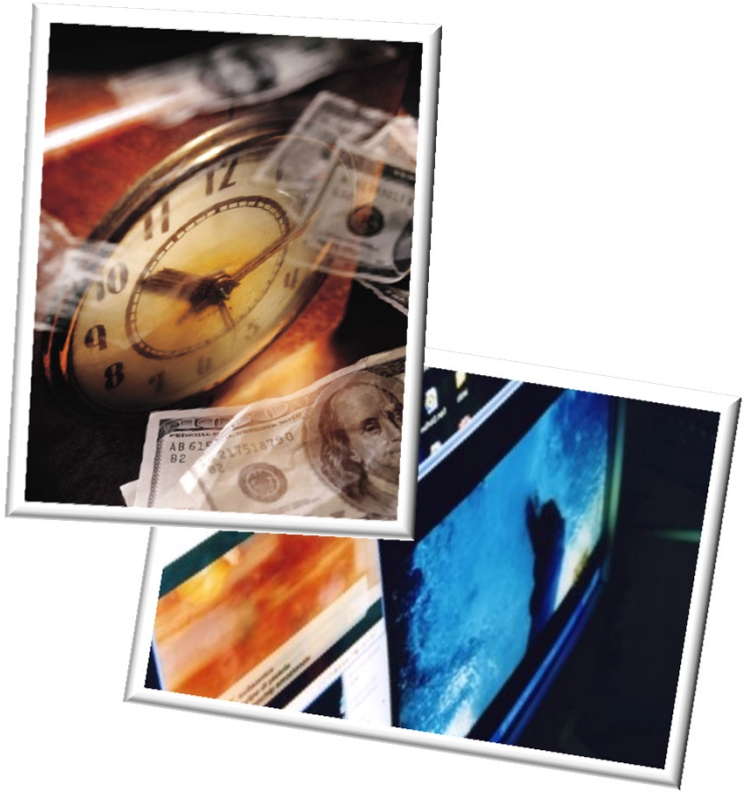
Clouds Solve Real Problems

There is a Reason for the Hype

Today's Clouds Solve Real Problems

… But Only Certain Kinds

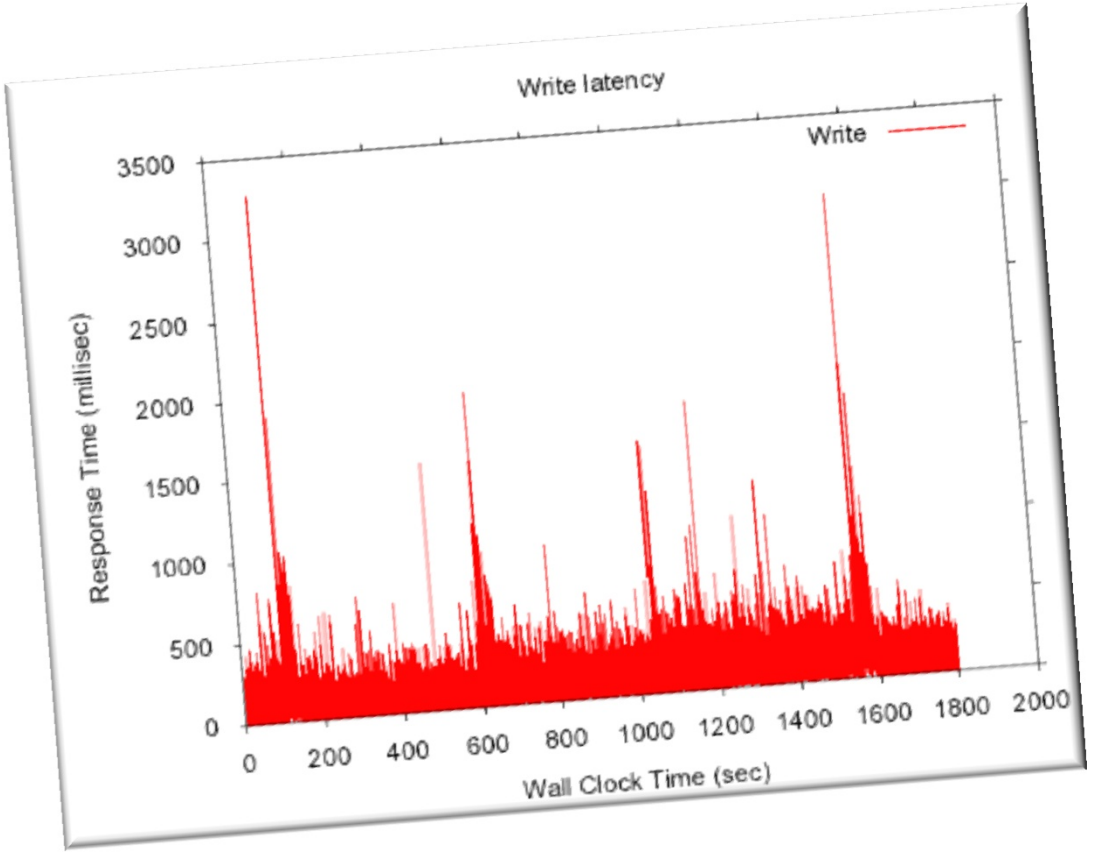
- Transaction oriented
- Stateless
- Relaxed time constraints



- Session oriented
- Stateful
- Stricter time constraints

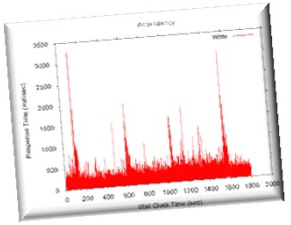
Example: Problems With Stateful Applications

Today's Clouds are Optimized for the Average, Accepting Huge Outliers



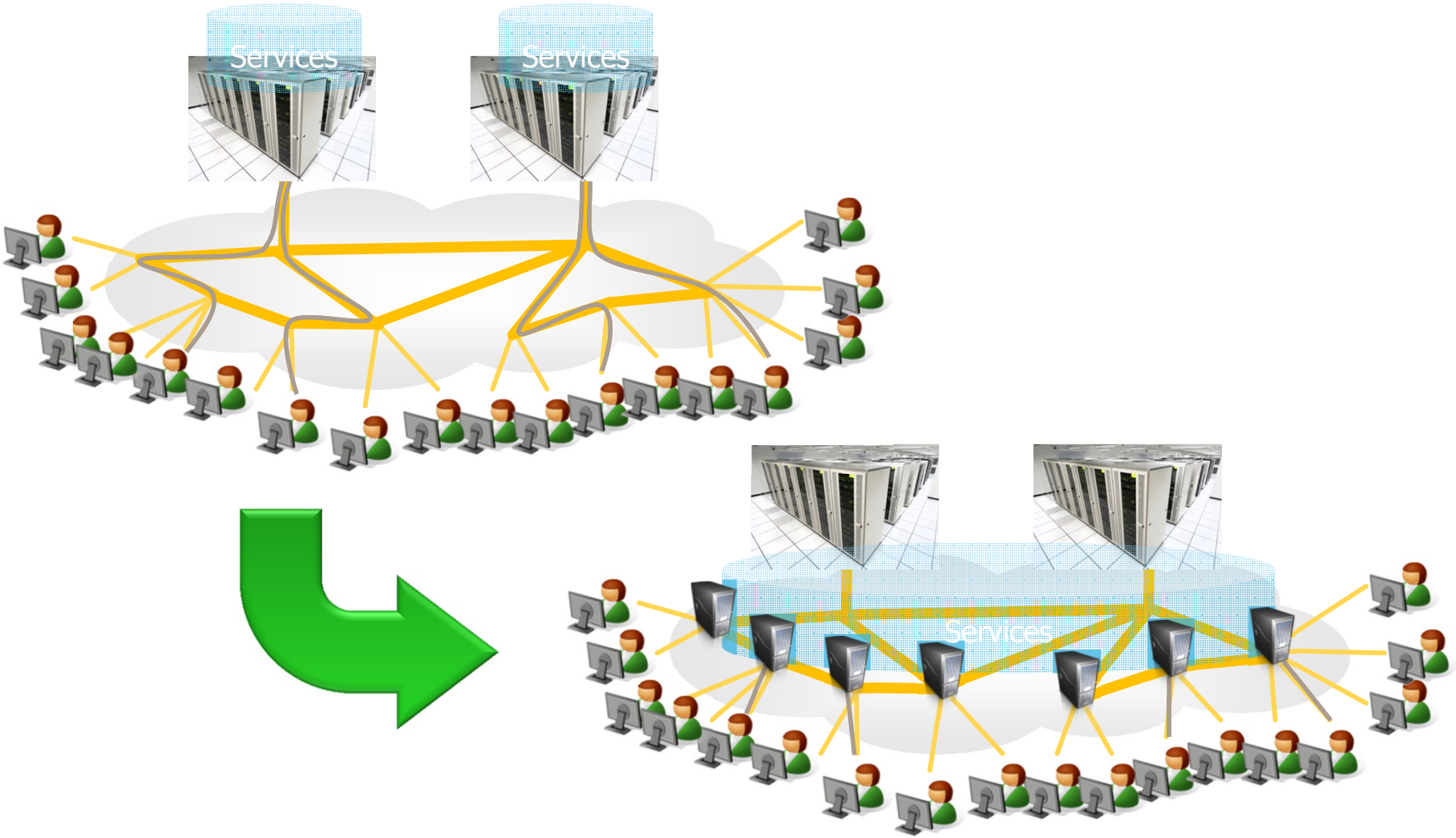
Is it possible?

Cloudifying the Wireless Access Infrastructure



From IT Cloud to Networked Cloud

Moving from Centralized Clouds to Highly Distributed Clouds



From IT Cloud to Networked Cloud

Taking the Network into Account – Why We need an Integrated Approach

Today's ecosystems set forth players at various layers, e.g.

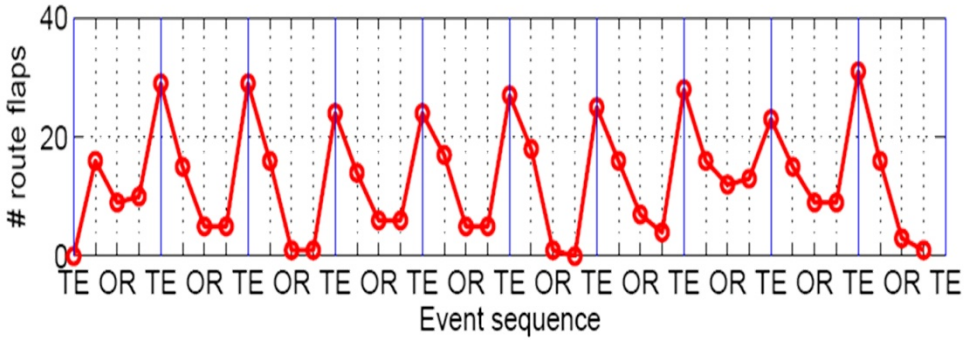
- Network providers,
- Overlay providers,
- Application and Content Providers.

Players at various layers often have conflicting objectives, e.g.

- Network providers may aim to balance network load, while
- Application-specific provider may aim to reduce latency.

Pursuing conflicting objectives will lead to instable networks, impairing all

=> *We need an integrated approach!*



From IT Cloud to Networked Cloud

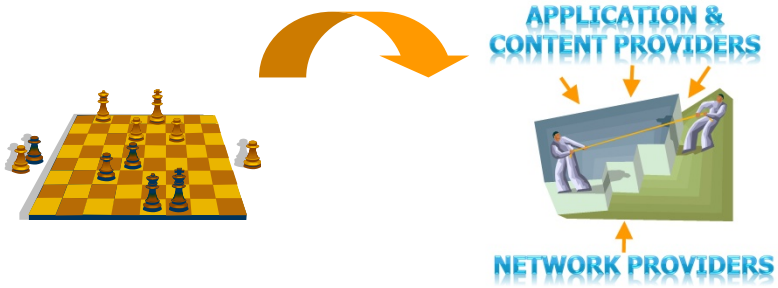
The Benefits of Cross-Layer Awareness

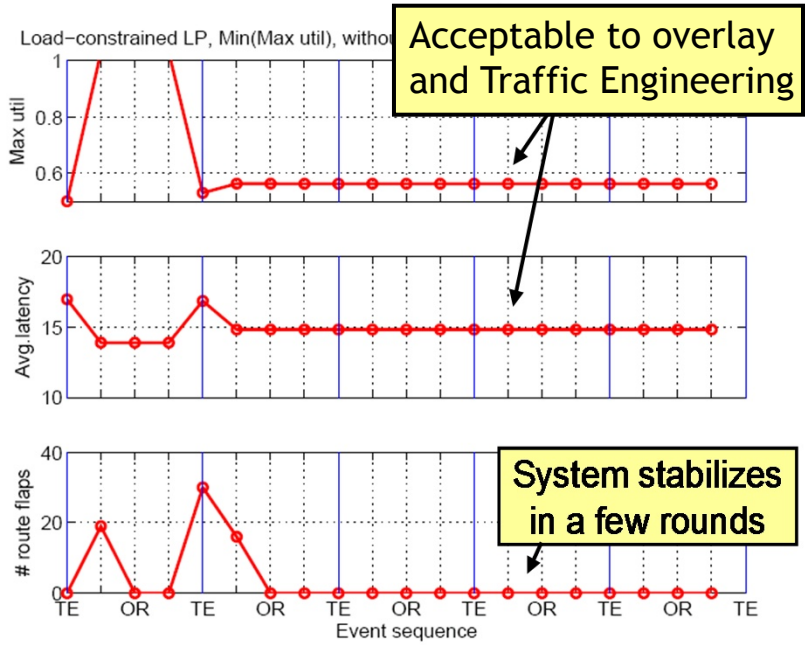
Our Approach: Apply game theory to the layer interaction problem.

- Leader makes route adjustments according to a defined strategy.
- Other layer reacts to this change as a selfish follower according to its objectives.
- Leader acts after predicting/counteracting the subsequent reaction of the follower.

We have developed and evaluated several strategies that

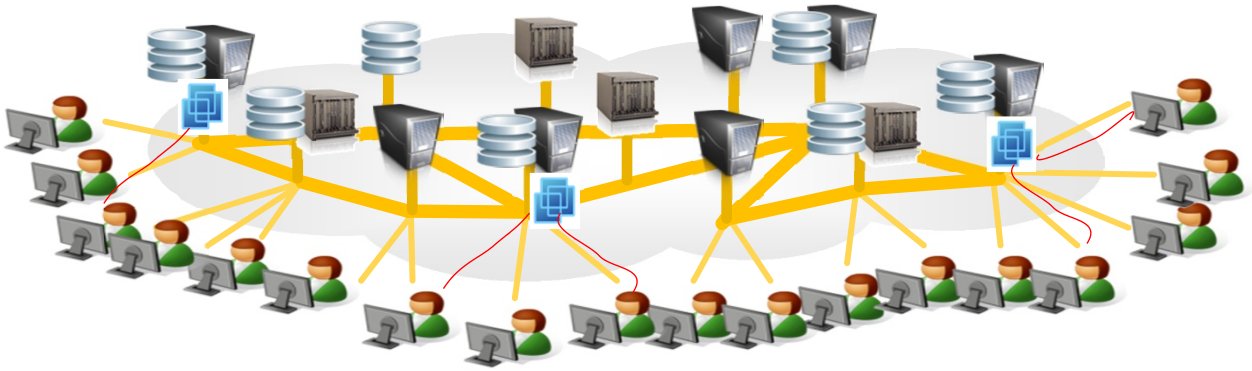
- Enable the leader to obtain the best possible performance, while
- Steering the system towards a stable state.





Networked Cloud – Differentiating Features

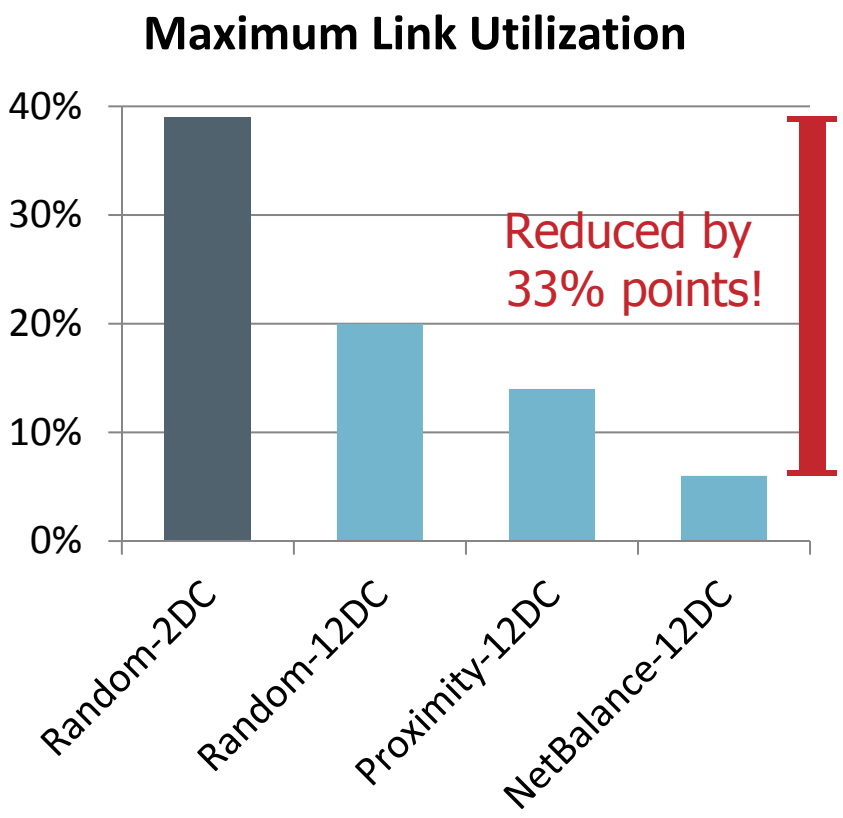
Benefits and Challenges

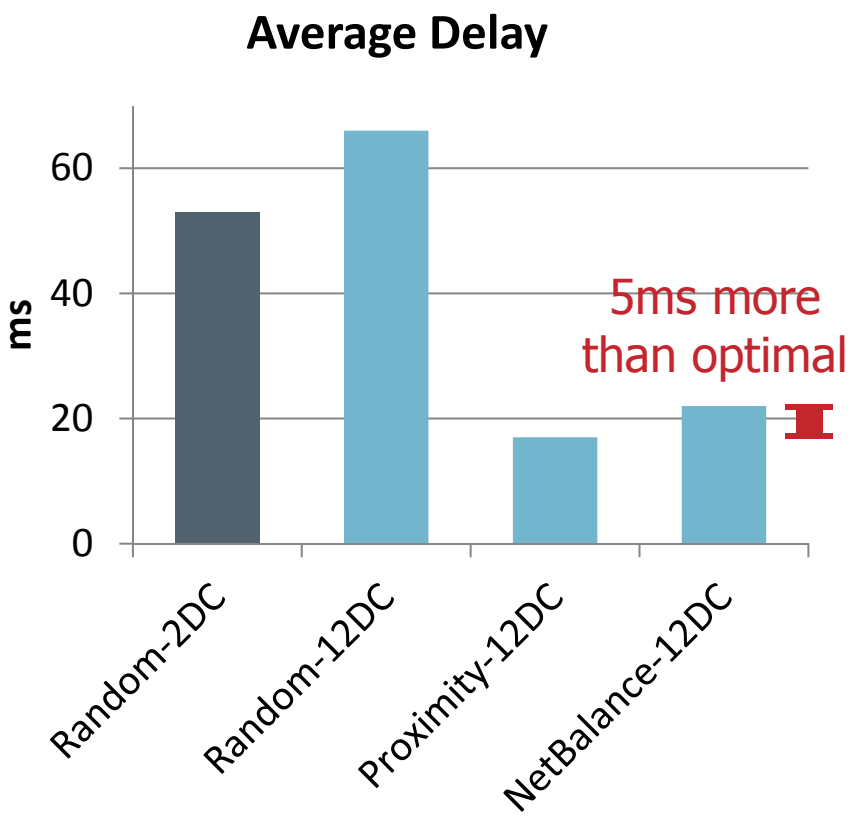


Feature of Networked Cloud	Benefit for customer	Provisioning challenge
Large number of smaller data centers (DC)	More choices to distribute and grow service	Produce best placement with unknown future requests
Service provider controlled interconnection	Integrated one stop solution for service	Be flexible in accommodating different resource constraints
Access to network routing	Load balanced service	Dynamic service routing
DC close to user	Low latency service	Handle two conflicting goals in placement
DC far from user	Built in disaster recovery	

Why Resource Placement Matters

Finding the right Location provides Benefits





What It Looks Like

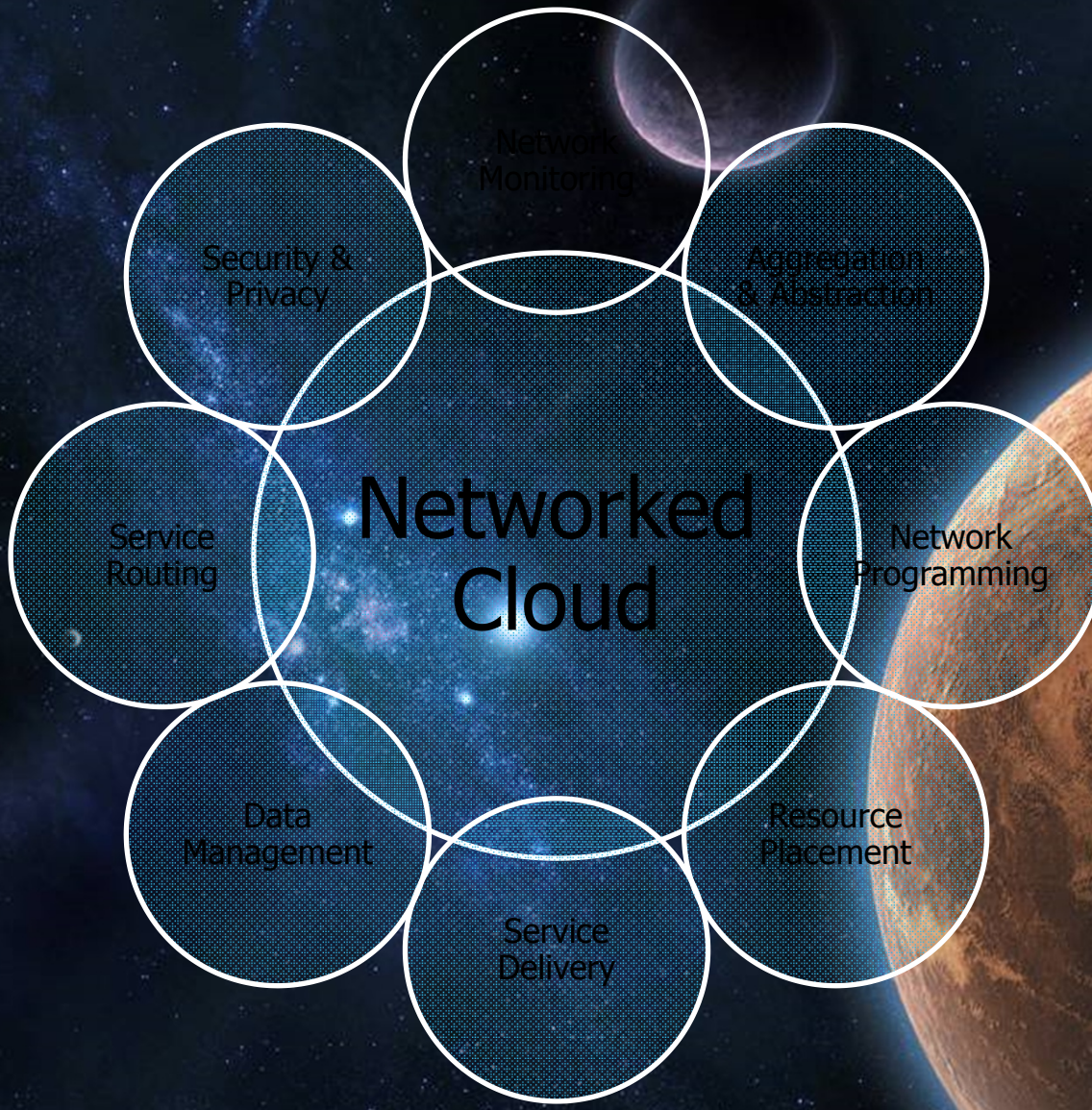
Developing an Industry Standard - Application-Layer Traffic Optimization

Server	# Tests Passed	# Tests Failed	# Tests Not Supported
BL/ALU	19	1	0
Server 2	19	0	1
Server 3	18	1	1
Server 4	4	0	16
Server 5	6	3	11

Bell Labs contributions in IETF

- Helped develop ALTO WG in IETF
- Co-chair of ALTO WG and IRTF P2P RG
- Developing BoF for ALTO extensions.

A Universe Of Opportunities



Looking Ahead

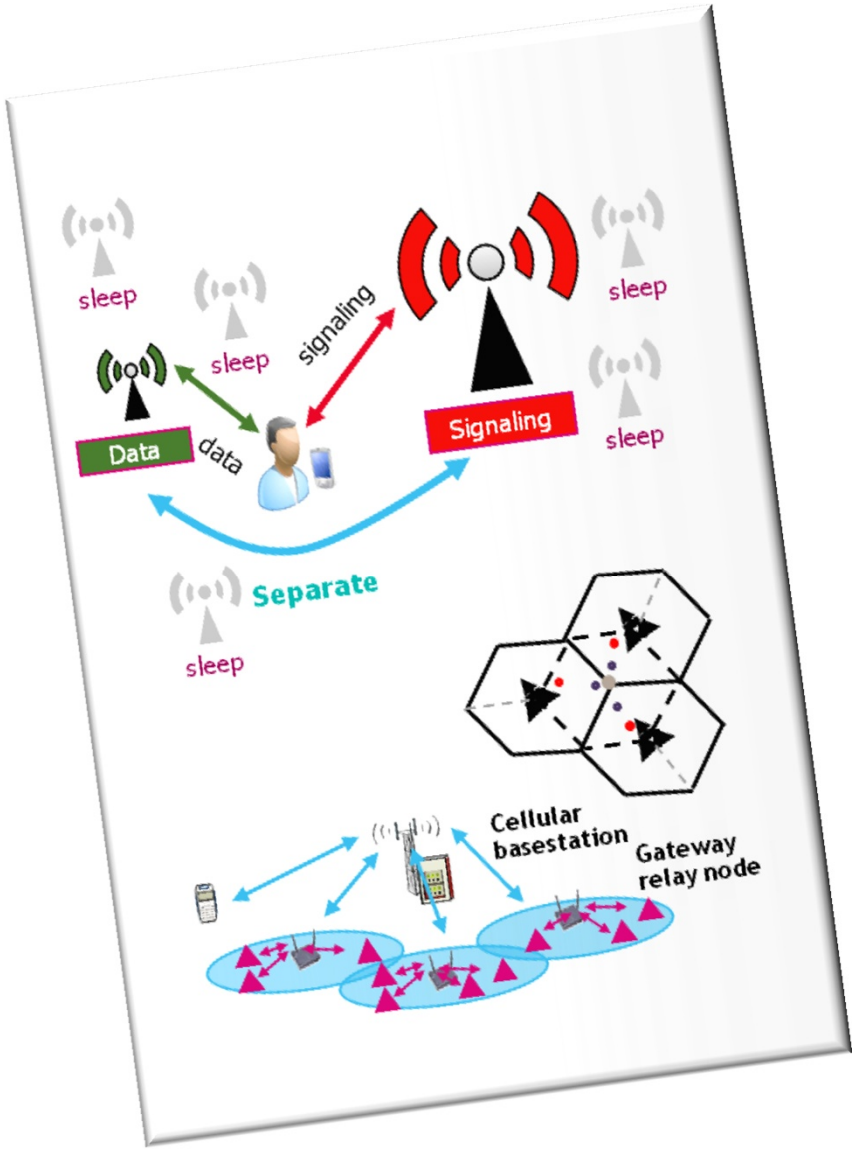
Innovation in Wireless – and Beyond…

Future wireless networks will:

- Efficiently support diverse data types,
- Provide a service rather than a bit rate,
- Embrace all of the standards: from Bluetooth and WLAN, CDMA, W-CDMA, LTE and new ones as well,
- Possibly separate signaling and data paths,

Cloud processing will dominate in the network.

Full convergence of wireless and wireline solutions

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Holistic