Clouds Without Data Centers

Markus Hofmann
Head of Bell Labs Research
Alcatel-Lucent

http://www.mhof.com/

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Clouds Solve Real Problems
There is a Reason for the Hype

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Today's Clouds Solve Real Problems
... But Only Certain Kinds
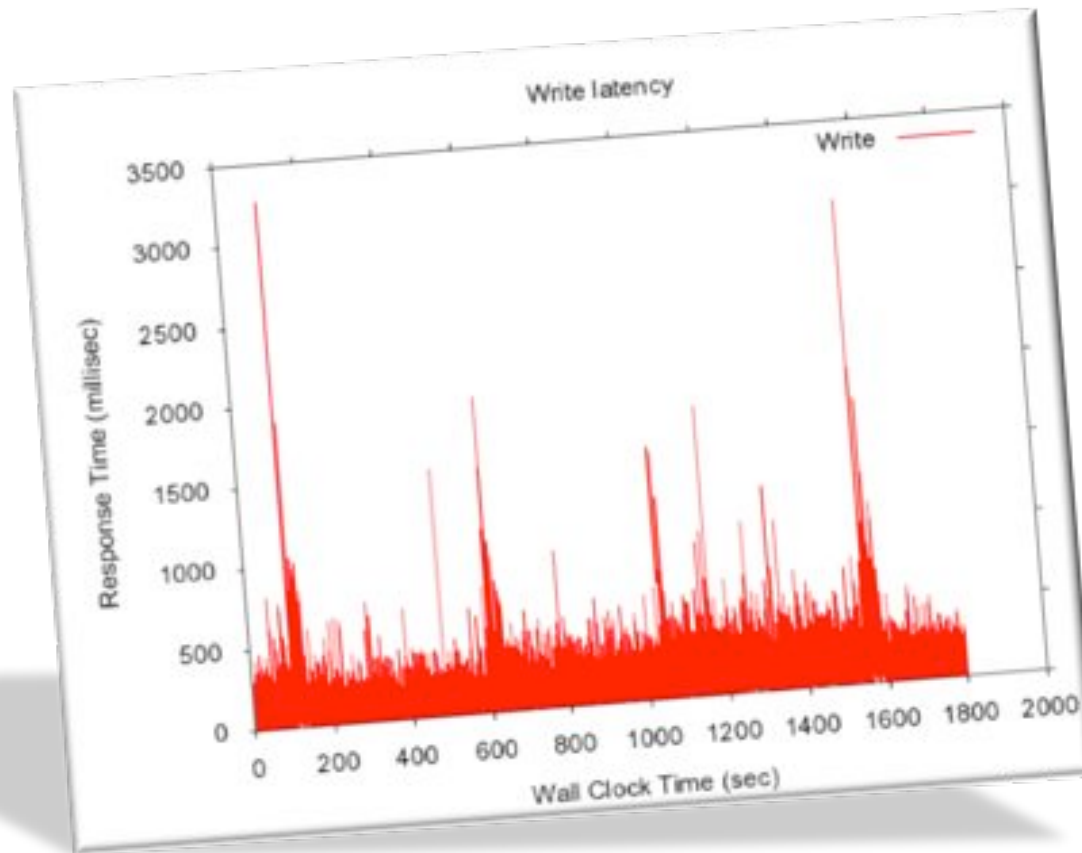

- Transaction oriented
- Stateless
- Relaxed time constraints
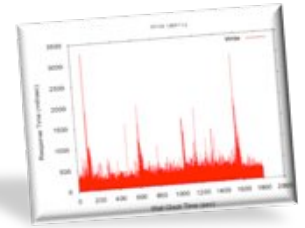
- Session oriented
- Stateful
- Stricter time constraints

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Example: Problems With Stateful Applications
Today's Clouds are Optimized for the Average, Accepting Huge Outliers
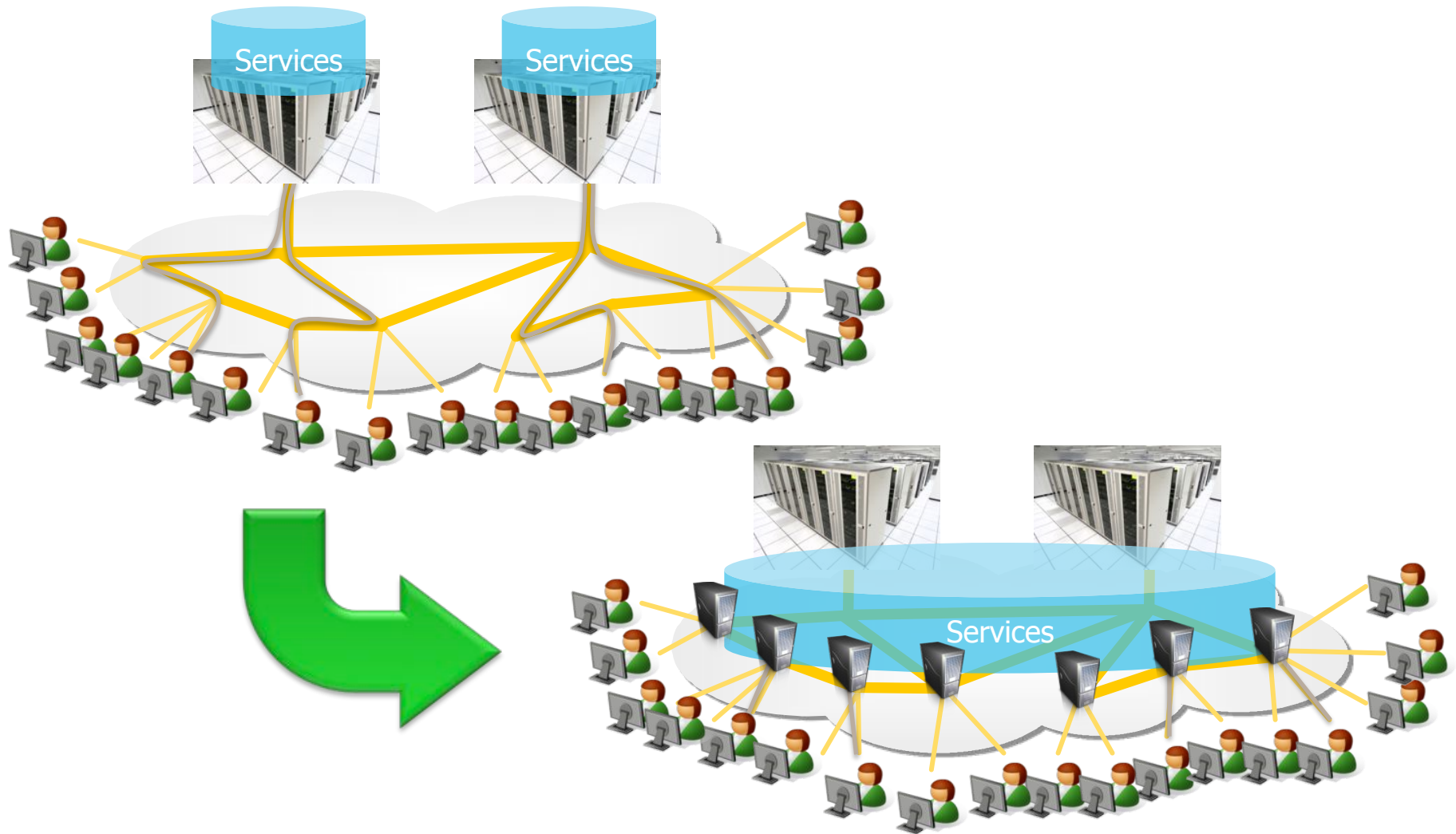
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Is it possible?
Cloudifying the Wireless Access Infrastructure

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From IT Cloud to Networked Cloud
Moving from Centralized Clouds to Highly Distributed Clouds

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The World Is My Data Center

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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!*

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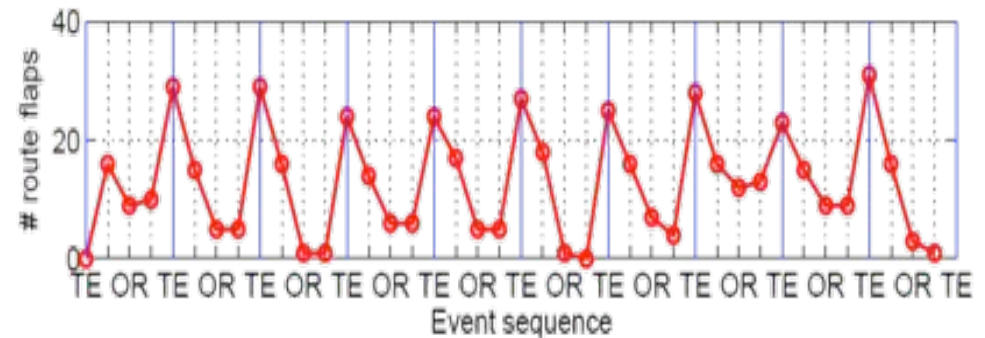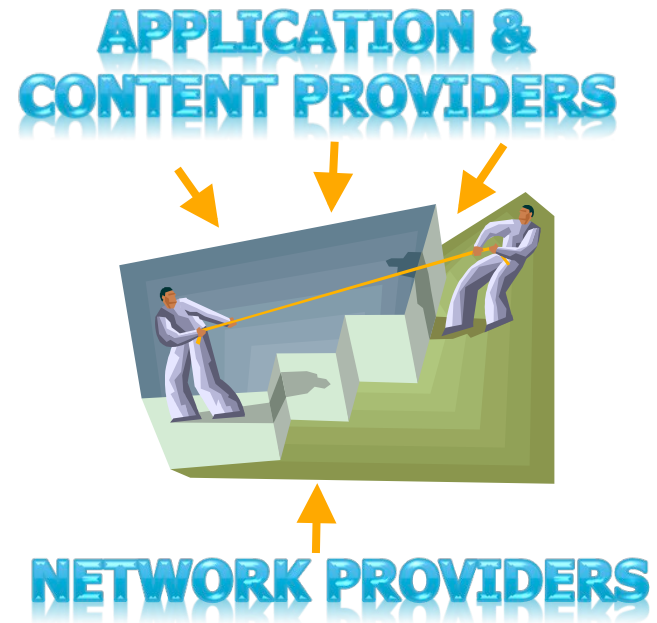
From IT Cloud to Networked Cloud
The Benefits of Cross-Layer Awareness

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.

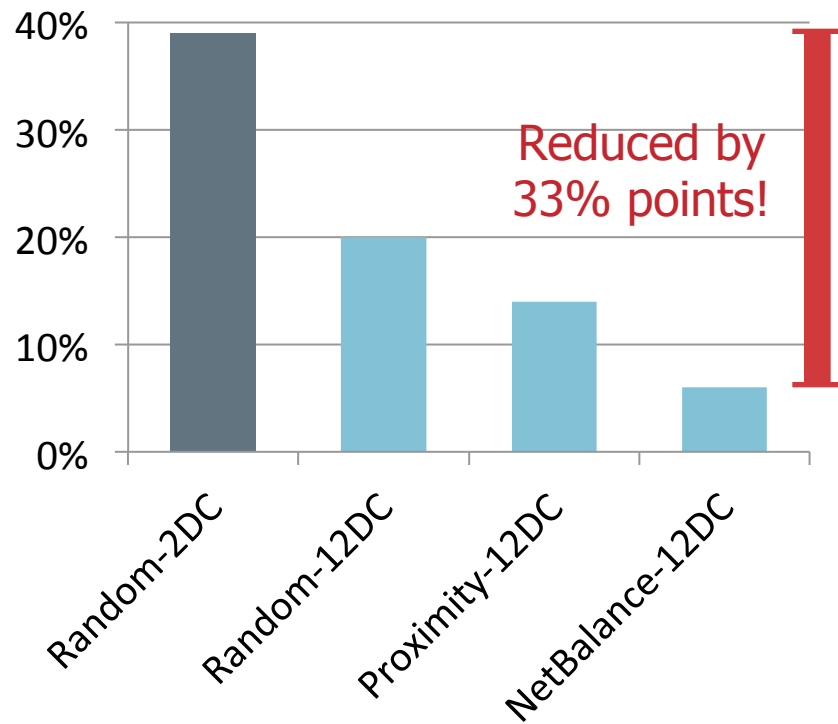We have developed and evaluated several strategies that

- Enable the leader to obtain the best possible performance, while

- Steering the system towards a stable state.

Acceptable to overlay and Traffic Engineering

System stabilizes in a few rounds

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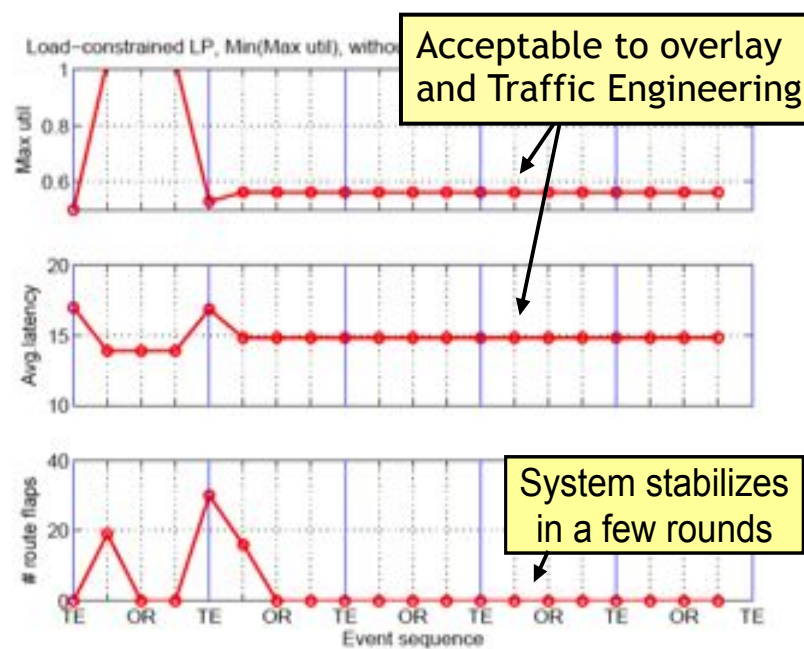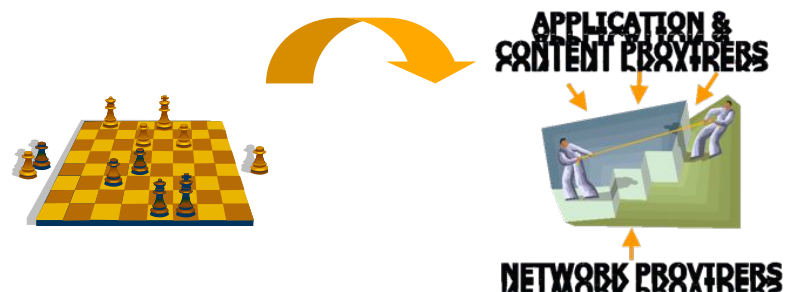
Why Resource Placement Matters
Finding the right Location provides Benefits

Maximum Link Utilization

40%

30%

20%

10%

0%

Reduced by 33% points!

Random-2DC   Random-12DC   Proximity-12DC   NetBalance-12DC

Average Delay

ms

60

40

20

0

5ms more than optimal

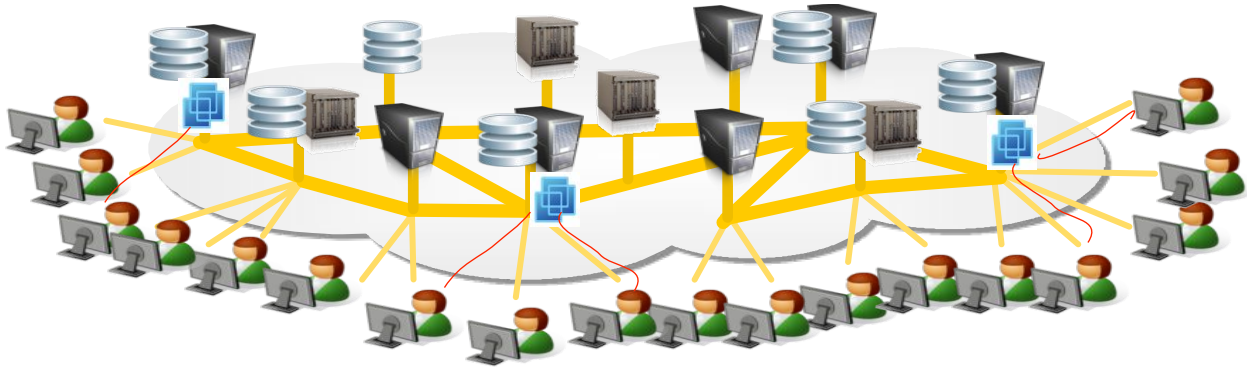Random-2DC   Random-12DC   Proximity-12DC   NetBalance-12DC

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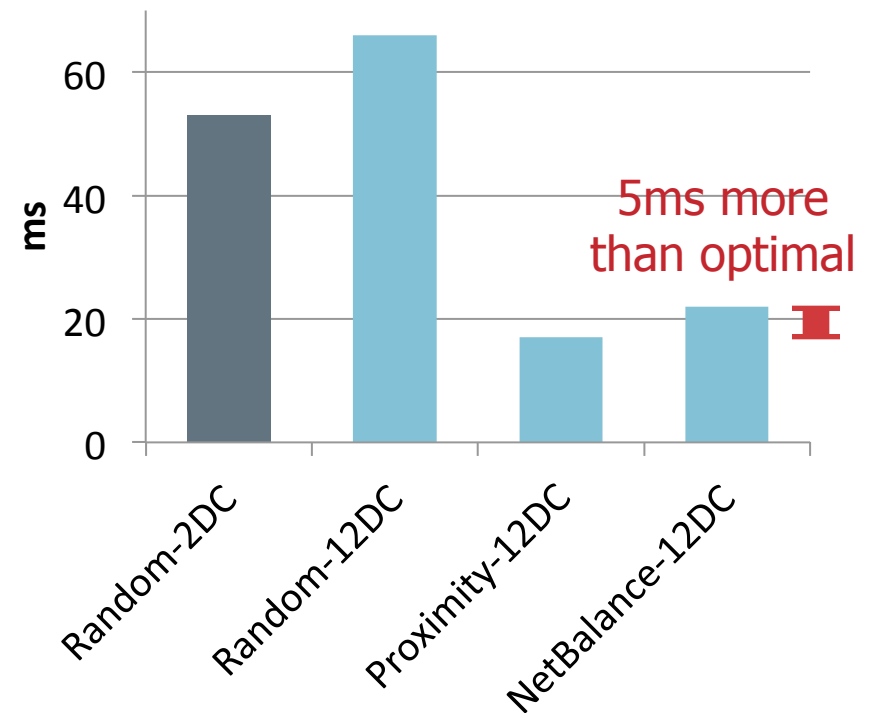
Networked Cloud – Differentiating Features
Benefits and Challenges

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	

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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.

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A Universe Of Opportunities
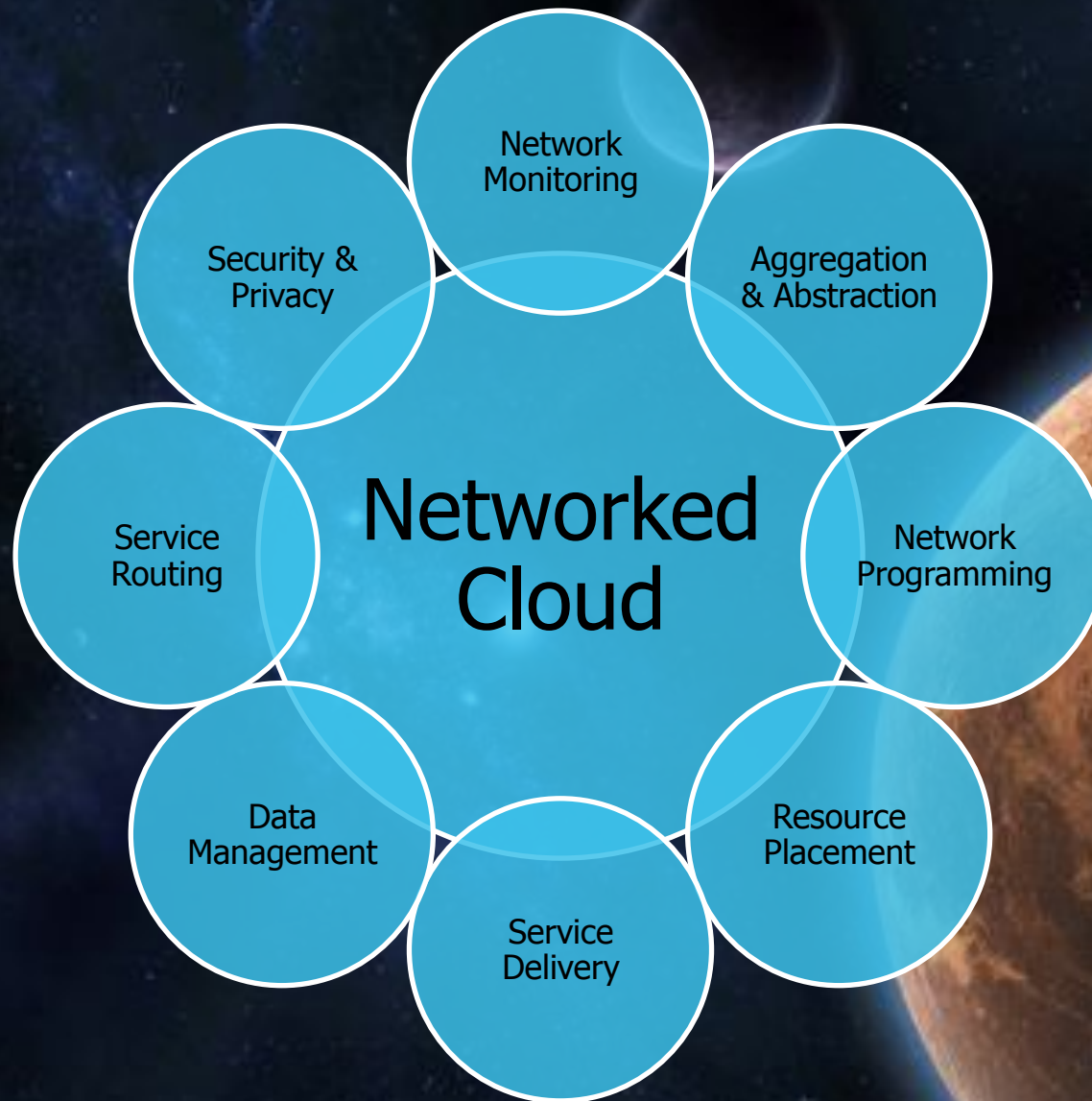
THANK YOU

Industrial Research

Fundamental & Applied

Global

Highly Cited

Integrated

Near & Longer Term

Preeminent

Complex Challenges

Cross-Disciplined

Collaborations

Holistic