

Raytheon BBN Technologies

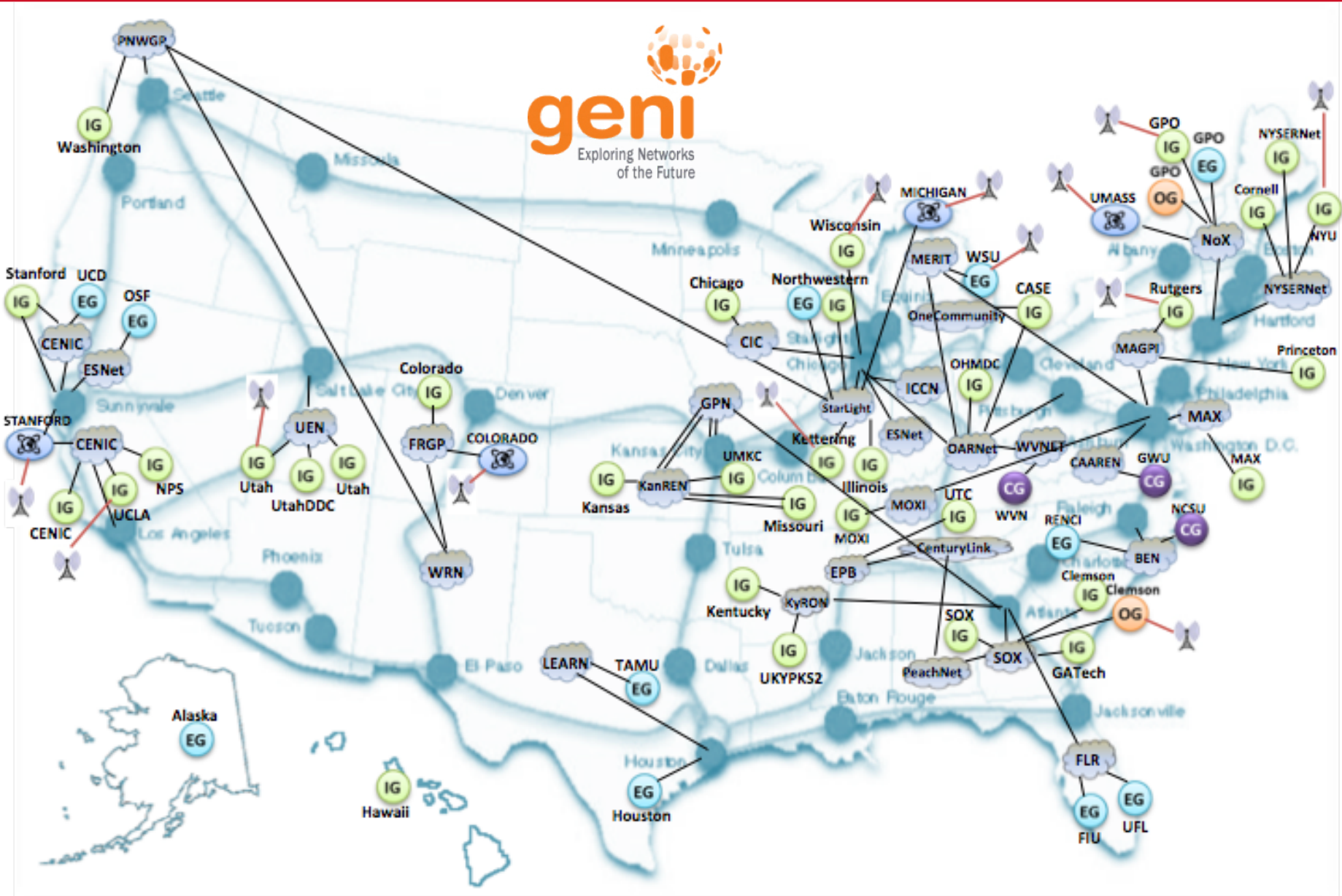
GENI and Beyond

Chip Elliott
BBN

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Raytheon
BBN Technologies

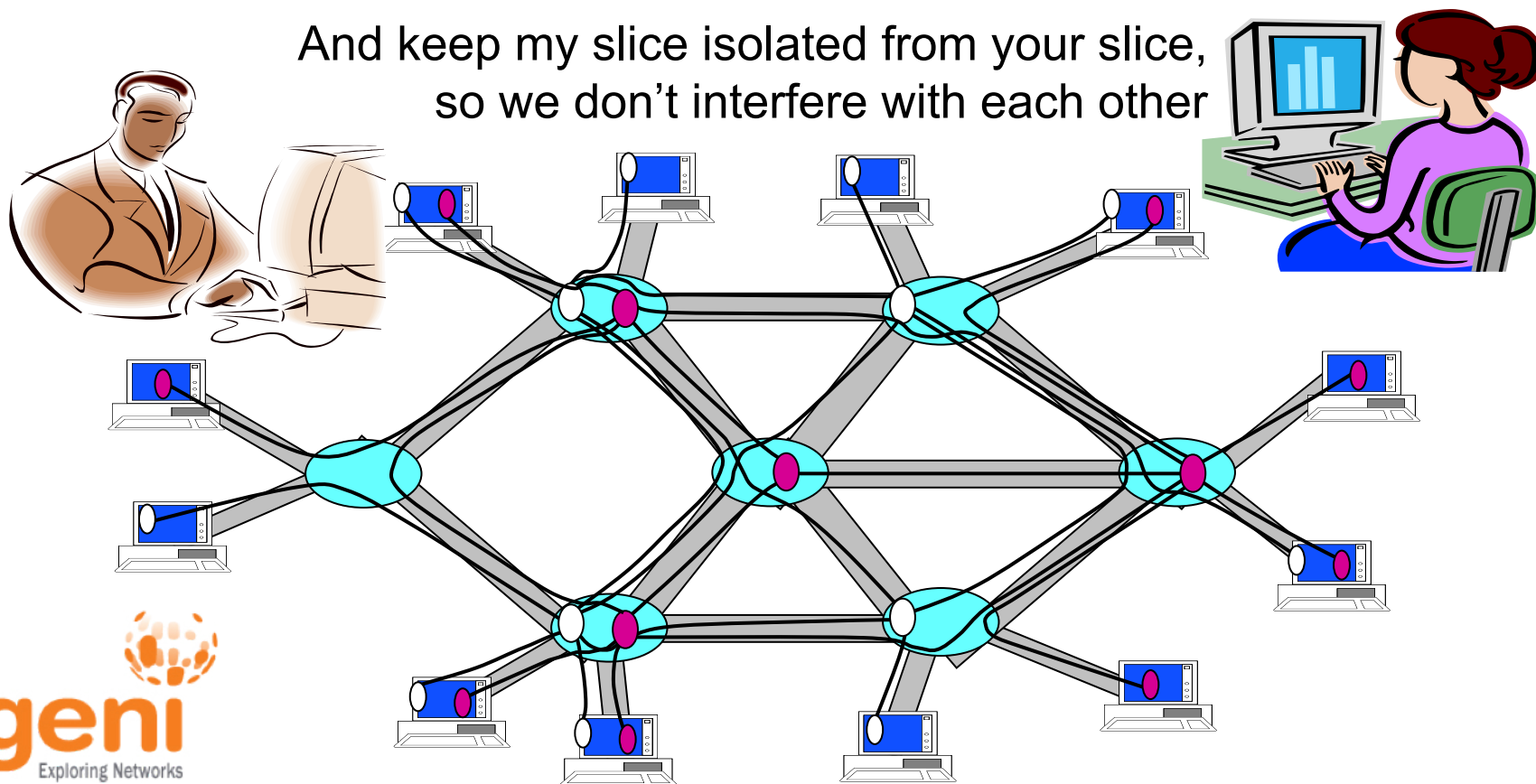
GENI – National infrastructure for research in next-gen networked systems



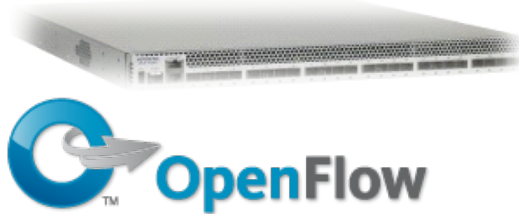
Slicing and deep programmability

Install the software I want *throughout* my network slice
(into firewalls, routers, clouds, ...)

And keep my slice isolated from your slice,
so we don't interfere with each other



Interconnected GENI Hardware

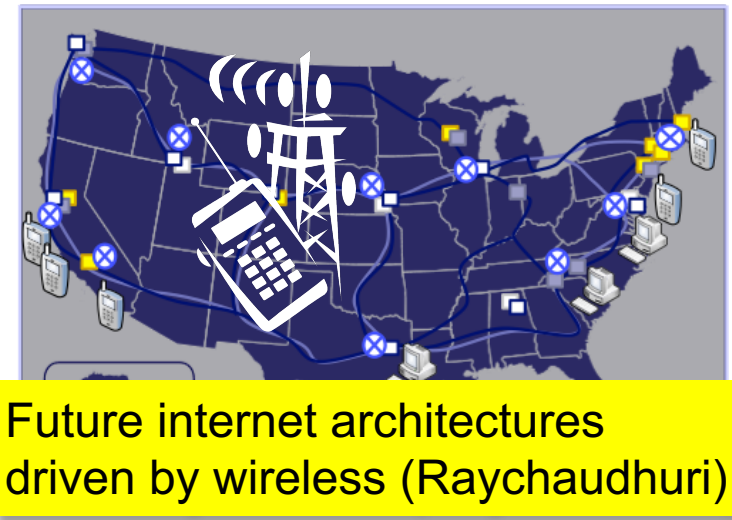
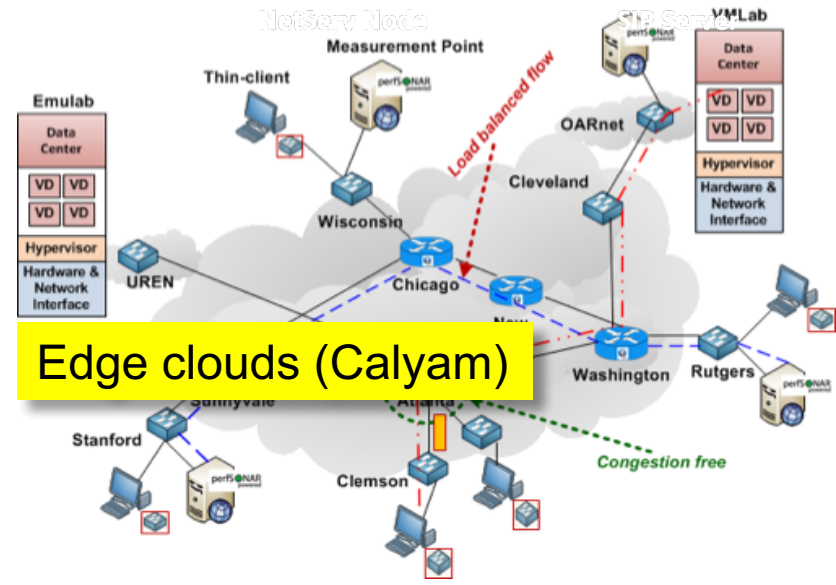
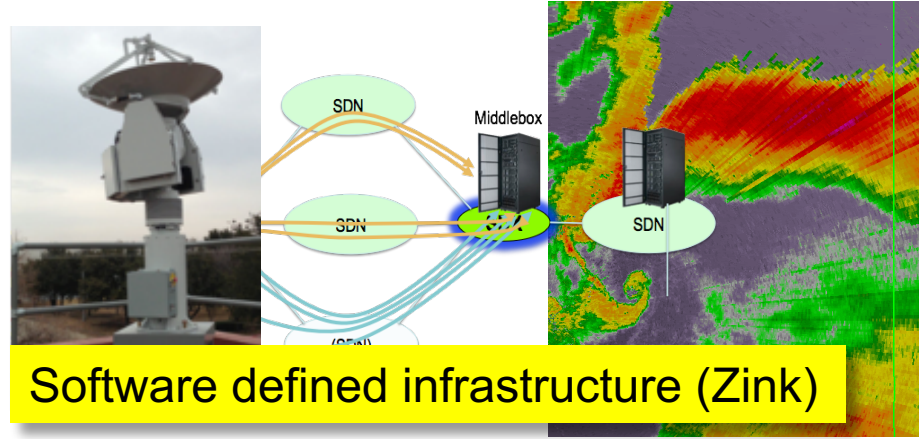


OpenFlow switches
(50+ campuses, regionals,
and national footprint)

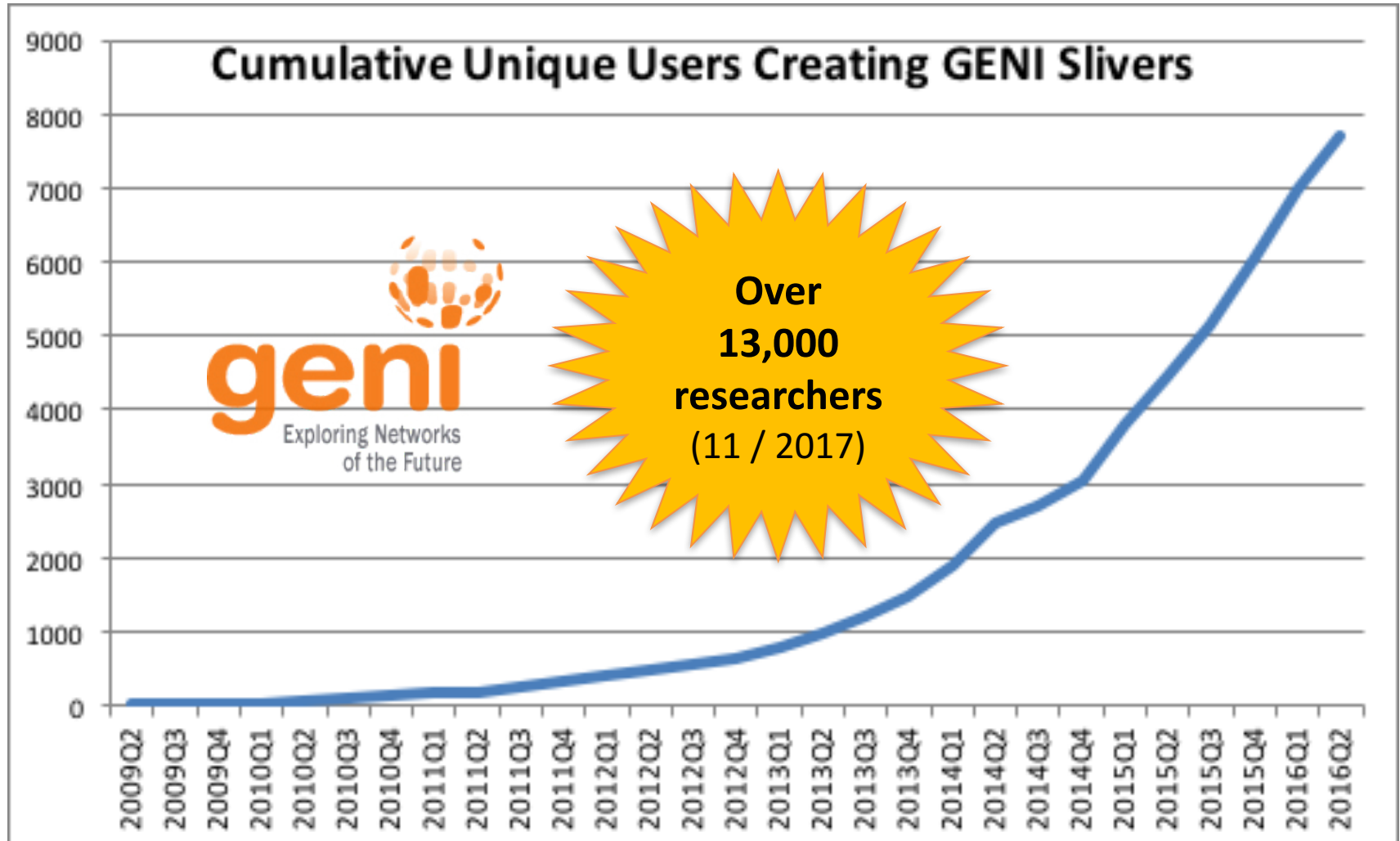
GENI Racks
(50+ campuses
plus regionals)

Research LTE Deployments
(20+ installations)

What research does GENI support?



GENI growth



NSF Cloud infrastructure

CloudLab

Chameleon



Rob Ricci



Kate Keahey

What is CloudLab / Chameleon ?

- A “meta-cloud” or “cloud factory”
 - not a cloud itself
 - rather, a facility for trying many kinds of clouds in parallel.
- Gives bare-metal access and control over a substantial set of computing, storage, and networking resources
- Researchers can install standard cloud software stacks, modify them, or create entirely new ones
- A key goal: enable repeatable research
 - It’s easy for researchers to get the same software and hardware environment to repeat or build upon each others’ work

The rise of global interoperability

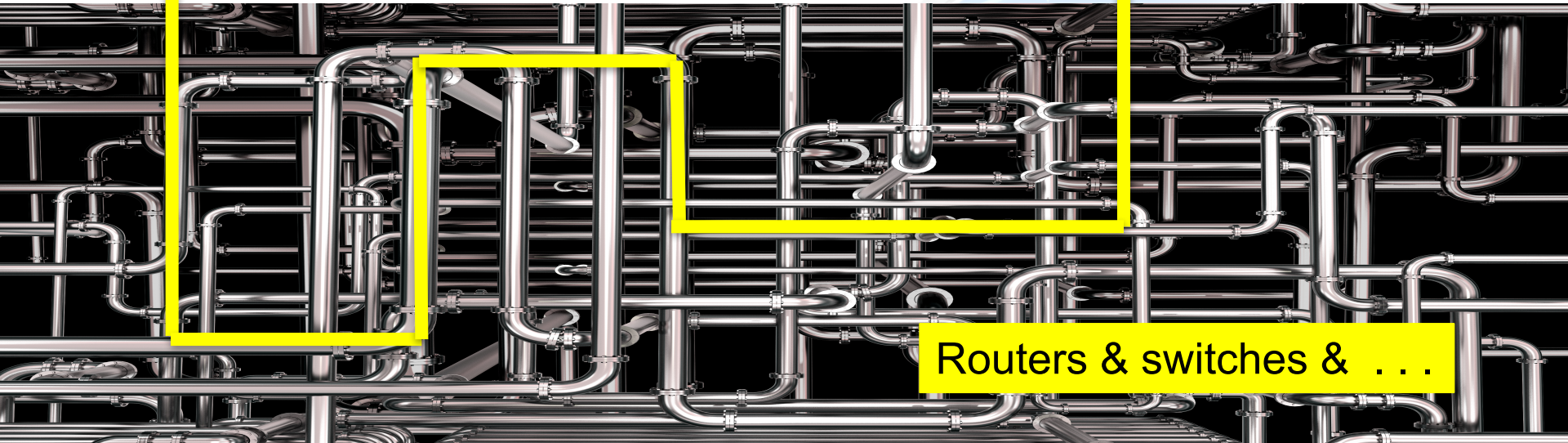
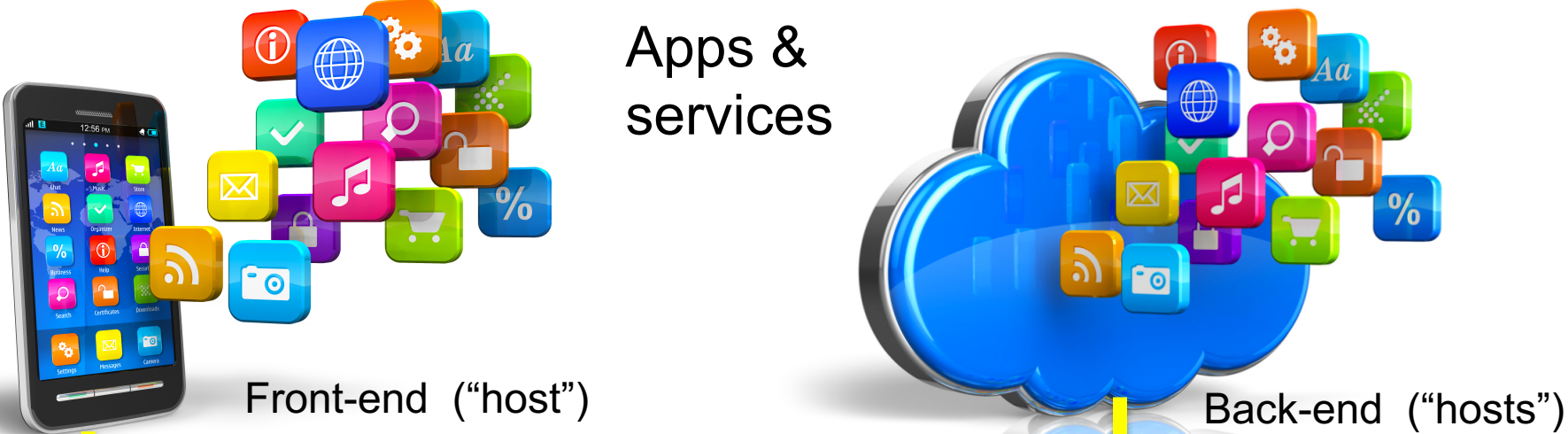


Working together as peers and equals to expand opportunities for researchers worldwide

Outline

- We're moving beyond the Internet
- Next up: "Cloud in the Loop"
- You are perfectly positioned

One view of today's Internet



Tomorrow's Internet ?



Apps & services

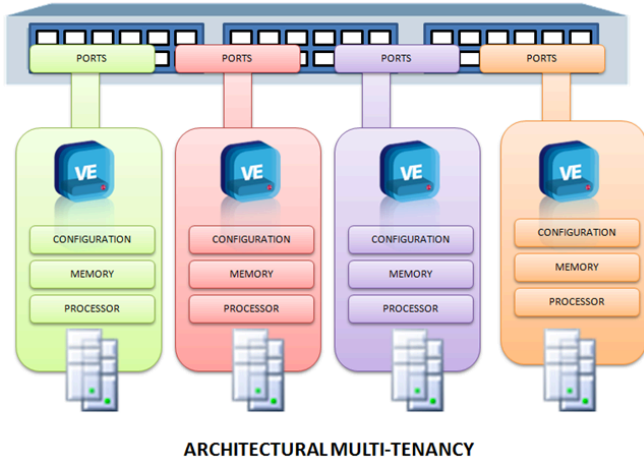
Front-end ("host")

Back-end ("hosts")



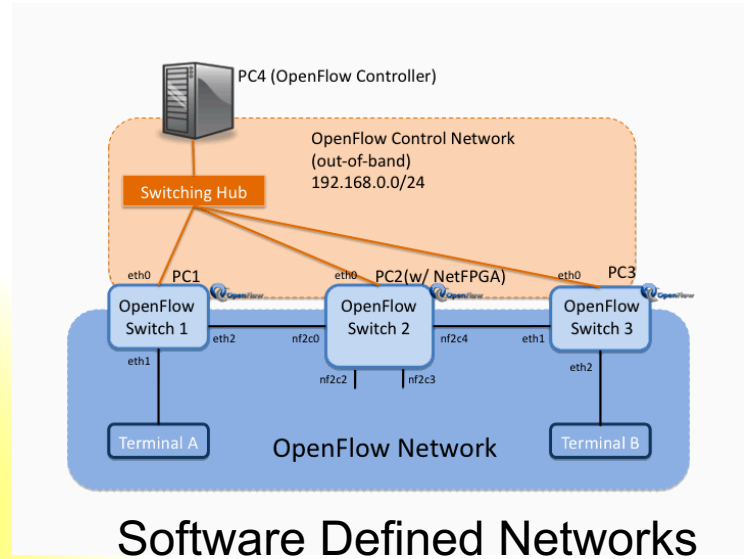
Apps & services permeate the fabric

Major trends are converging



Multi-tenant Datacenters Infrastructure

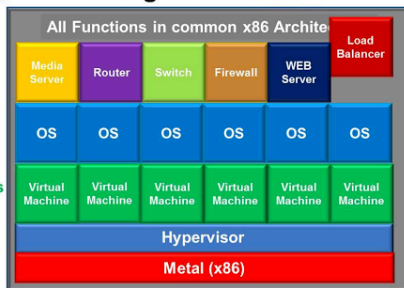
Software Defined Infrastructure



Network Functions Virtualization (NFV)

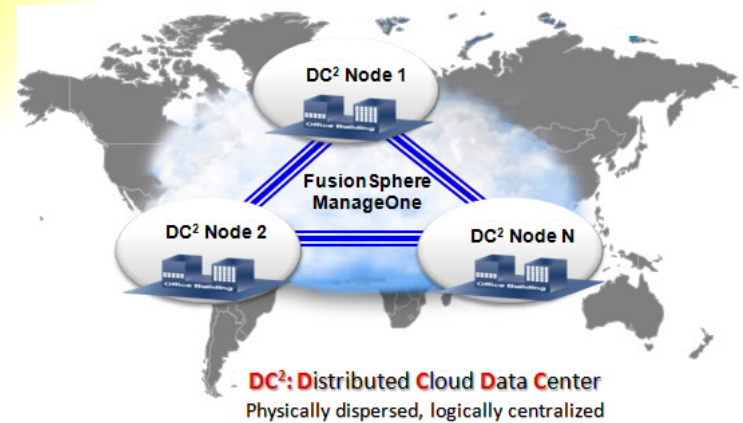
- Standard Hardware
- Less Complex
- Very Flexible
- Reduced Power
- Lower CapEx
- Lower OpEx
- Test new apps
- Low risk
- Reduced TTM
- Open Market to Software suppliers

Using Virtualization



Network Functions Virtualization (NFV)

Chip Elliott



Distributed Datacenters

GENI and Beyond

Driving the transformation - A radical change in “router” economics

Economics now favor pervasive computation and storage



ARPANET Imp (1969)

1 core, clock ~ 1.1 MHz
64 Kbytes RAM
No disk

Today's cost: ~ \$650,000

Disk + controller (IBM 1302)
Today's cost: ~ \$2,545,000

Disks were too expensive in 1969

Commodity GENI rack

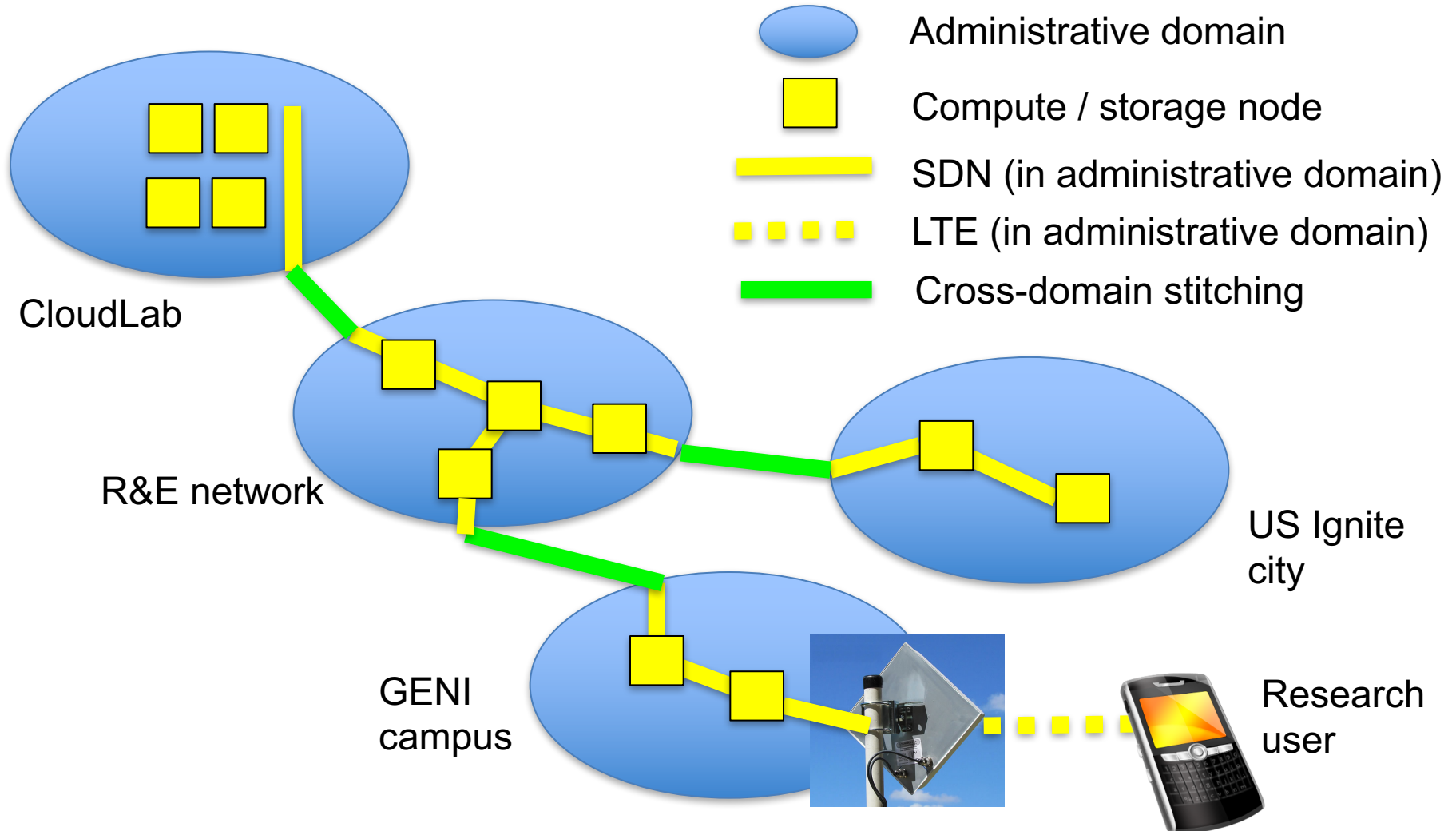
Each 1U=
32 cores, 2.1 GHz
16 Gbyte, 4 Tbyte

Today's cost: \$200,000
for full rack (50 x 1U)

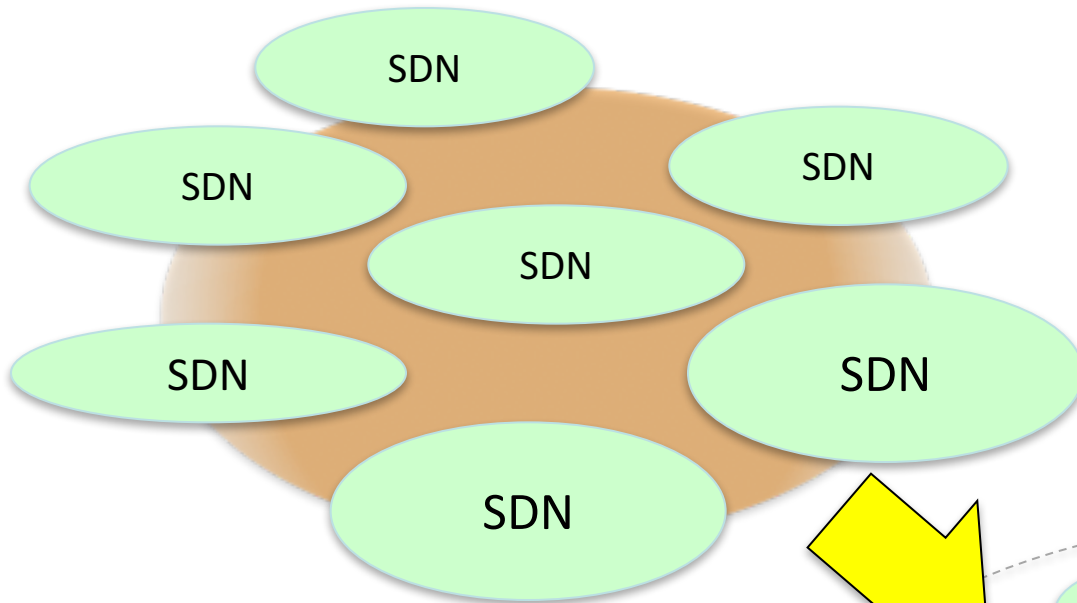


1/3 the IMP's price, but
with 1500 cores and 200
Tbytes of local storage

GENI / NSF Cloud / US Ignite = a prototype of multi-domain SDI

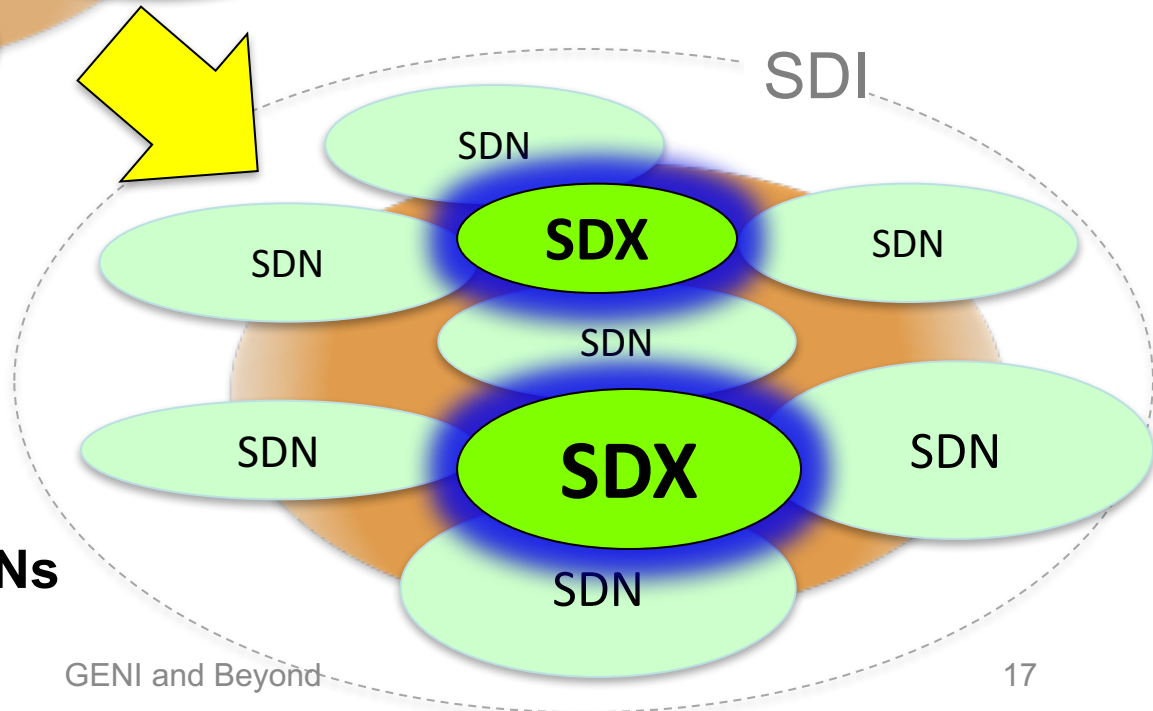


Software Defined Exchanges (SDX)



Today: “SDN islands”
GENI slices & VLAN stitching
help point the way

Next Step: Add SDX's
Build a “Rev 0” control plane,
run native next-gen apps
and scientific instruments
spanning multi-domain SDNs



What is an SDX ?

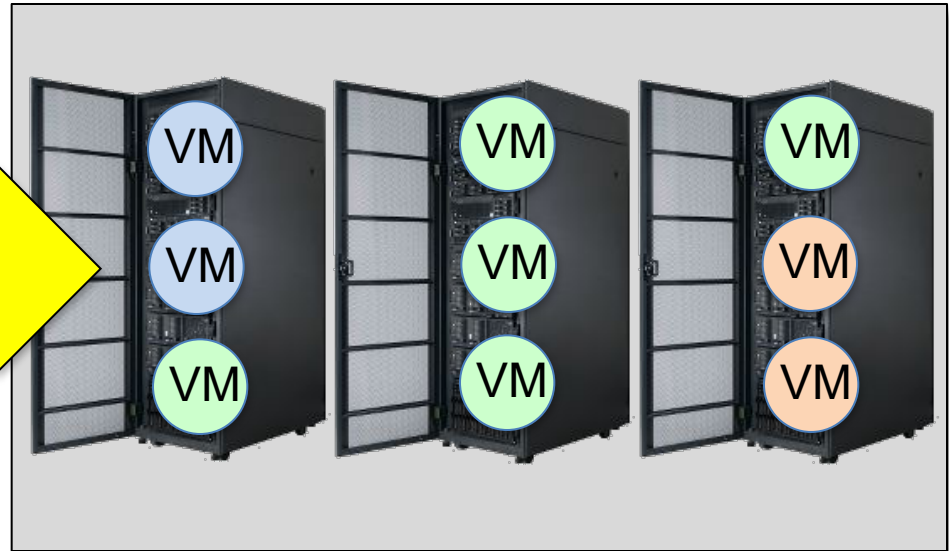
A range of SDX ideas and use cases



- “Near-term” SDX – pure connectivity/ROUTING
 - Layer 3 (IP) – e.g., connect AS’s
 - Layer 2 (Ethernet) – e.g., multi-domain circuits
 - SDN – connect SDN islands
- “Advanced” SDX – with compute/storage
 - Connect SDI islands
 - Compute / storage / network / instruments
 - GENI as an early instance

What does a **Virtualized Meet-Me Point** look like?

Software Defined Infrastructure !



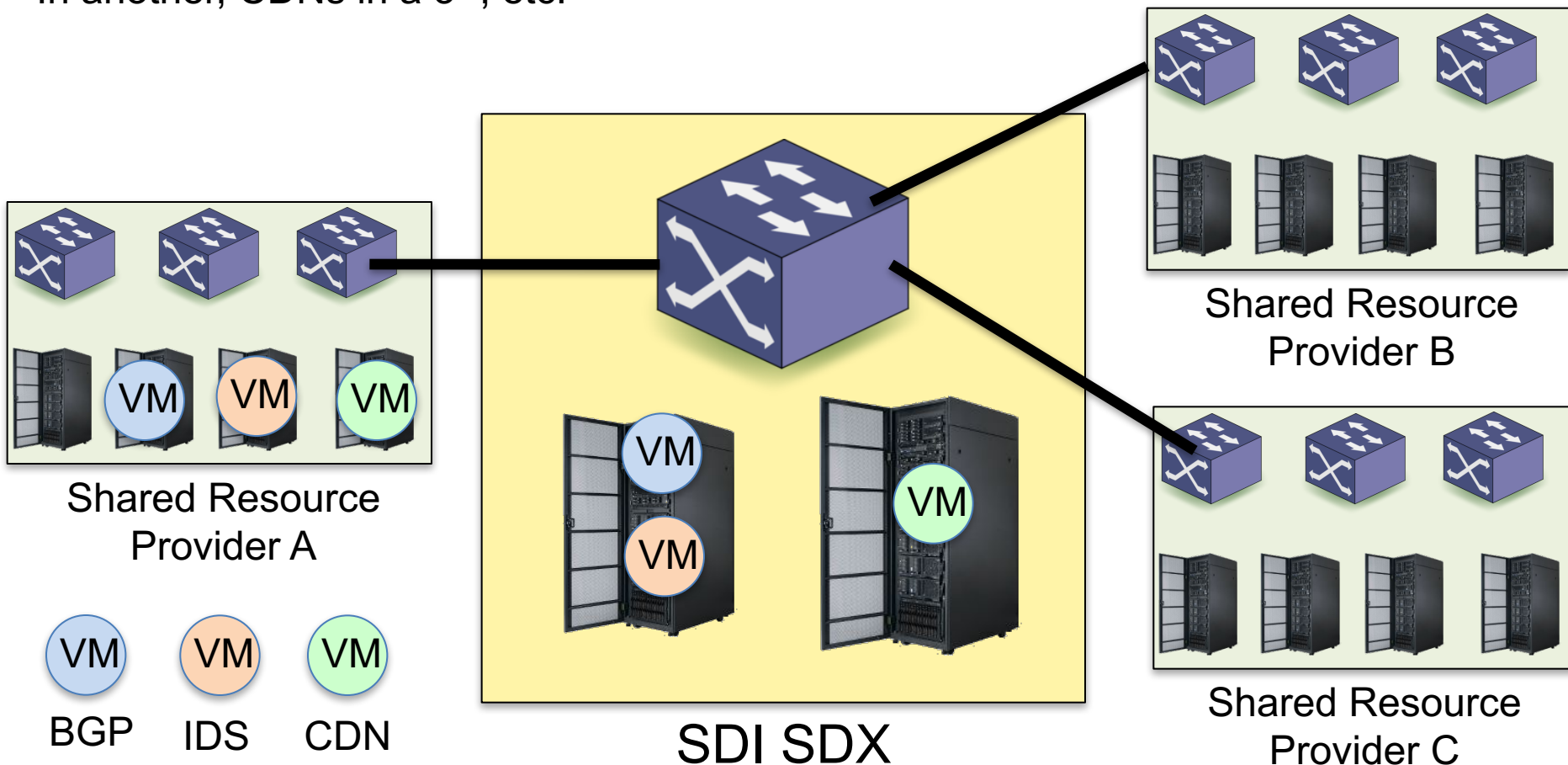
Physical Meet-Me Point (Colo) Virtualized Meet-Me Point

- Bring your own equipment
- Cages keep us physically separate
- Bring your own VMs
- Multi-tenant (slicing) keeps us separate

Software Defined Exchanges (SDXs)

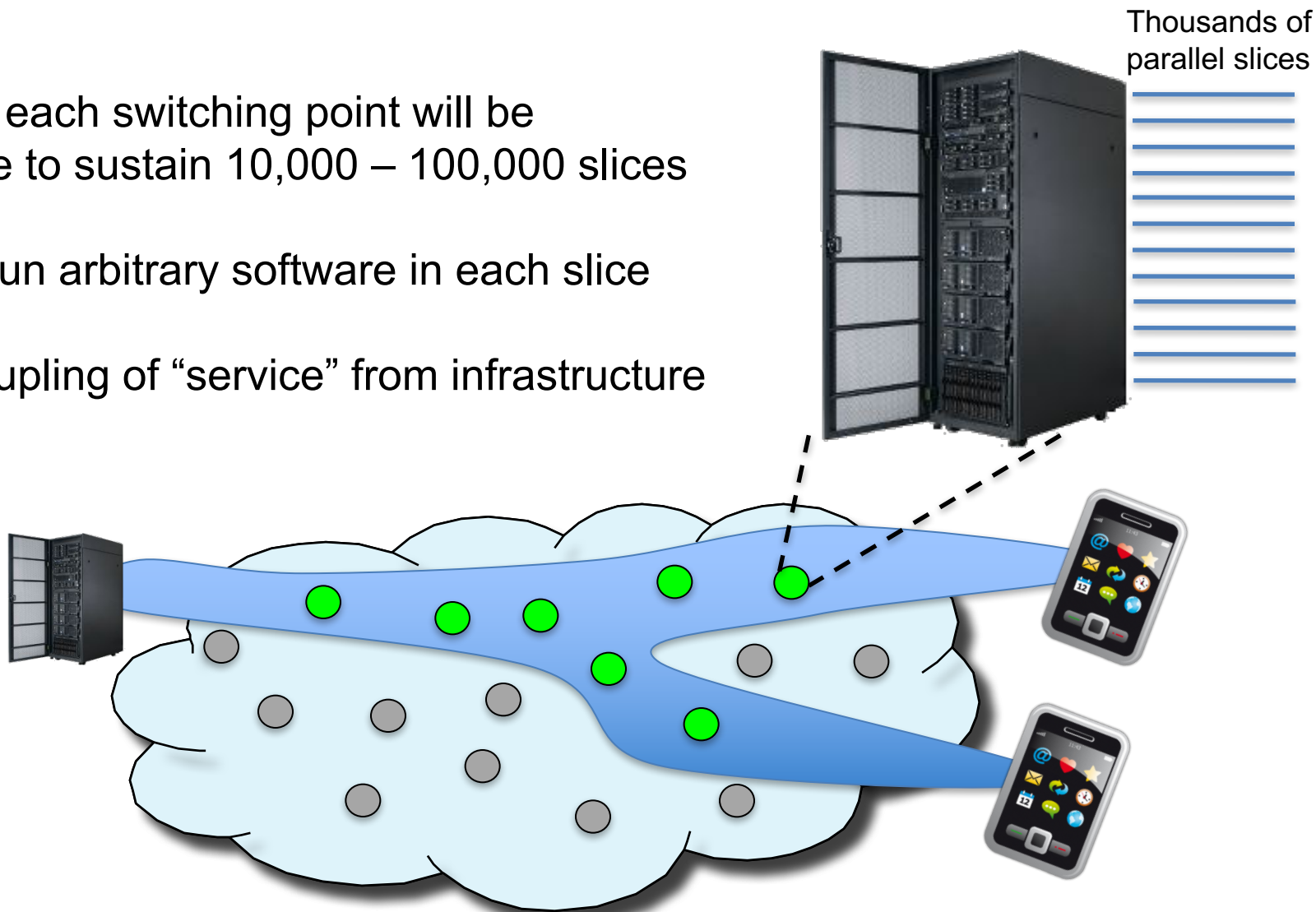
A “meet me” point for *services*,
e.g., BGP in one slice, Ethernet circuits
In another, CDNs in a 3rd, etc.

Key research areas: federations, authN/Z,
policy logics, cross-domain visibility, etc.



Instantiating services into slices

- Soon each switching point will be able to sustain 10,000 – 100,000 slices
- Can run arbitrary software in each slice
- Decoupling of “service” from infrastructure



The Rise of the “Service Store”

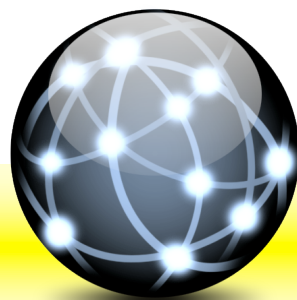
- “Drag and drop” Services
- Like an App Store . . .
- . . . that instantiates end-to-end Services



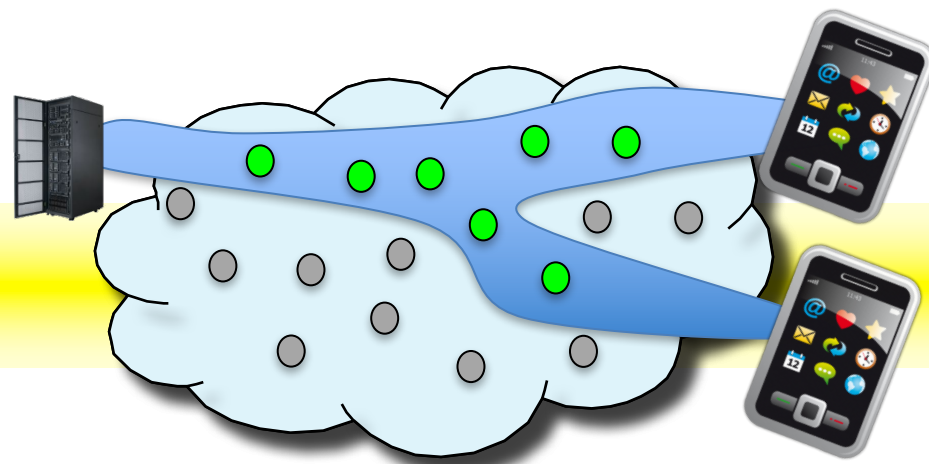
Decoupling Service from Provider



Service Store



Tailored Service

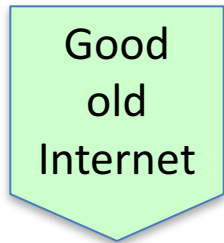


Service instantiated in a slice

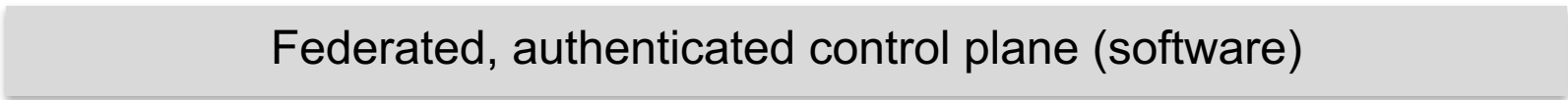
Software Defined Infrastructure

Looking beyond the Internet

SDI apps



Software Defined Infra.



Multiple, federated sites with interconnected Software Defined Infrastructure

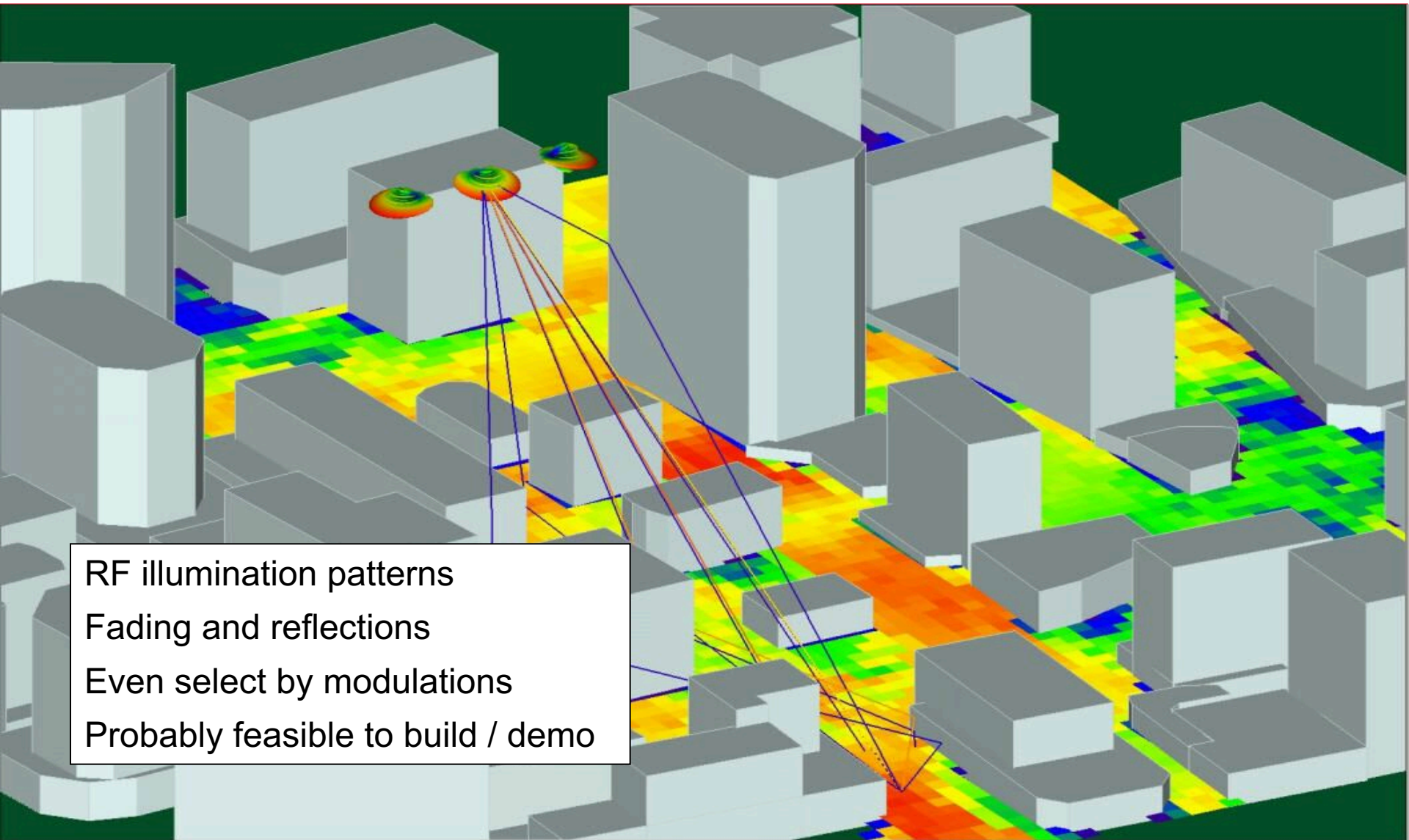
Outline

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- Next up: “Cloud in the Loop”
- You are perfectly positioned

A handy invention



If we built an RF equivalent . . . ?



What will we see in 20 years ?

- A world drenched in RF
- Much fuller spectrum occupancy than today
- Many, many illuminators with a wide variety of radiation patterns (lots of beams)
- Many very agile illuminators (beam steering, spectrum, coding, distributed beam forming, etc etc)
- Many flickering, mobile illuminators

Kind of like this, everywhere

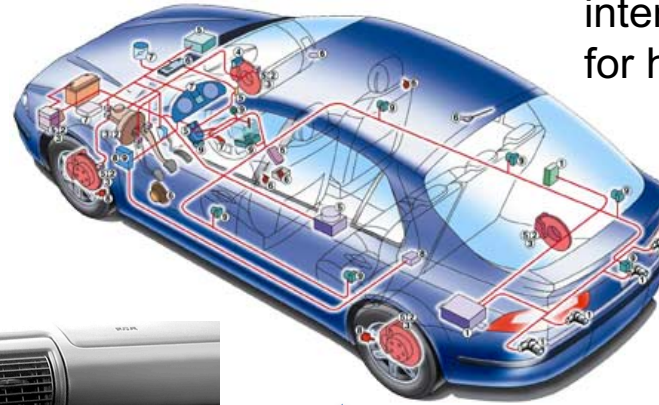


A thought experiment

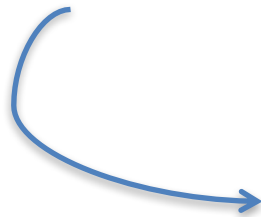
What if there were no embedded systems?



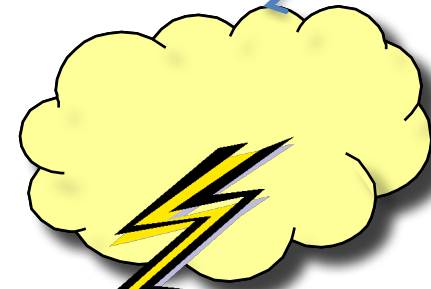
A really bad idea



“Bring your own” car control system - an interesting but crazy idea for human-driven cars



A somewhat better idea
(needs open interfaces)

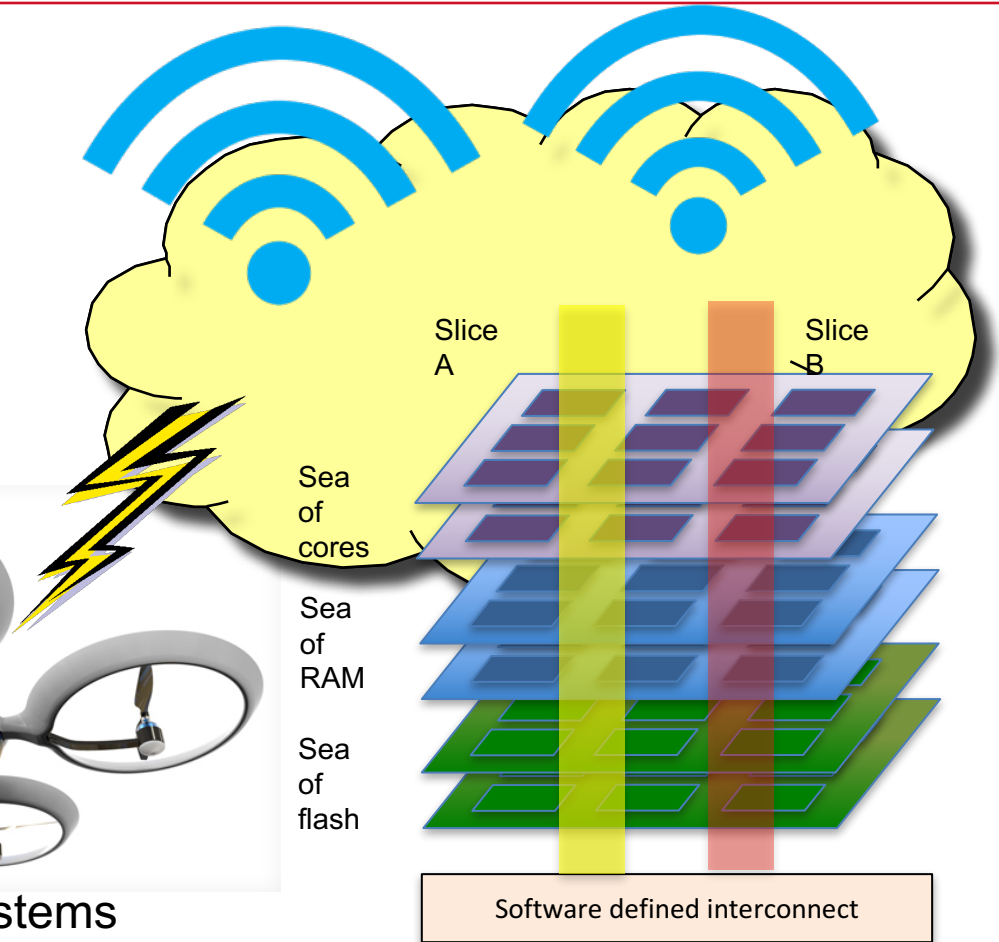


“Cloud in the Loop”

Let's build & use a very high performance realtime cloud

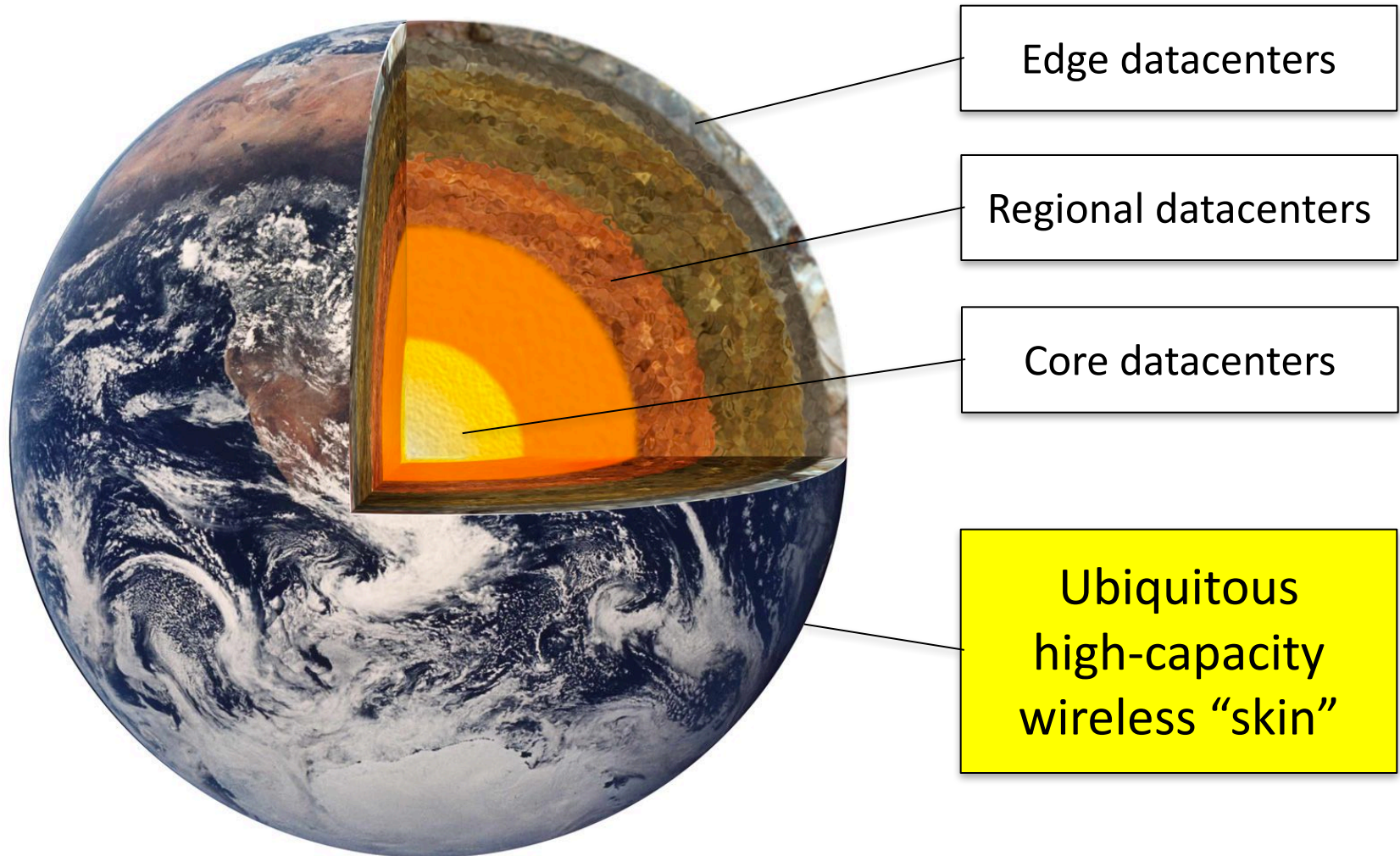


Realtime robotic systems

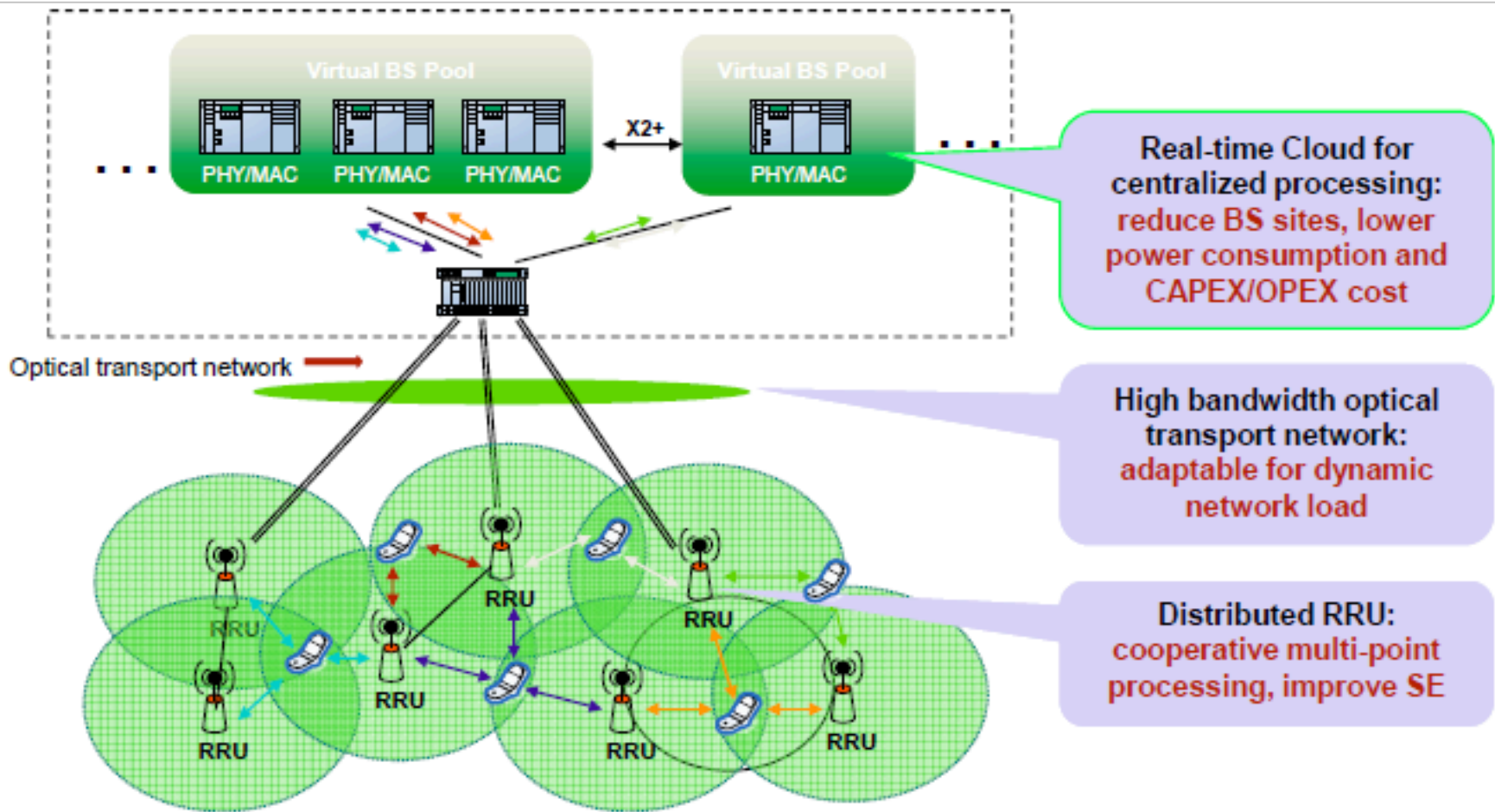


Tightly couple high-throughput racks with low latency wireless (5G?)

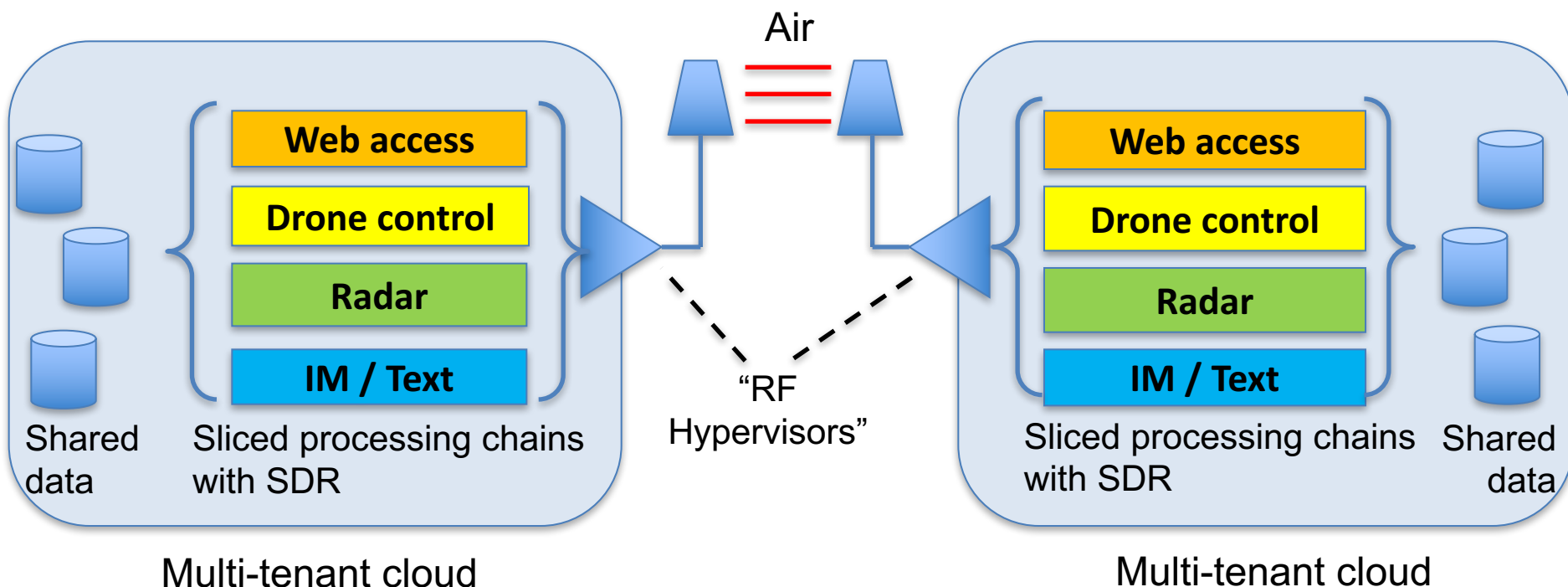
When Everything is the Cloud Wireless is the Cloud's Skin



A first step into this new world Cloud Radio Access Networks (CRANs)

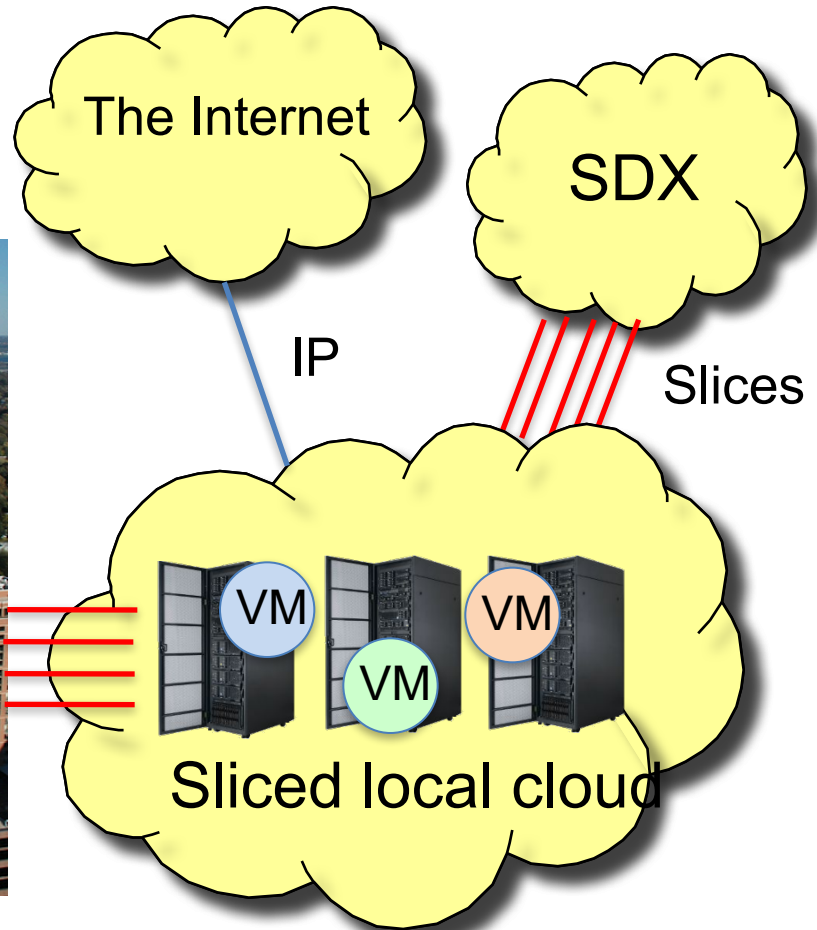
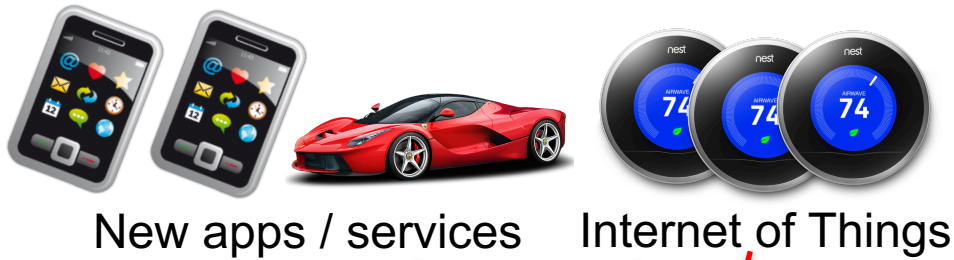


“Cloud in the Loop” schematic



- A fundamentally sliced (multi-tenant) architecture
- Software Defined Radios w/ multiple back ends (pub sub)
- Multifunction RF, all software-defined
- **Cloud-style, not telco-style**

The very exciting NSF “PAWR” Project

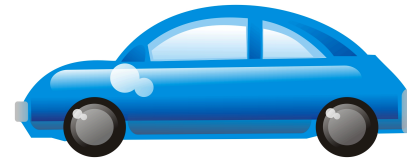


Next generation citywide wireless coverage with many radio access points

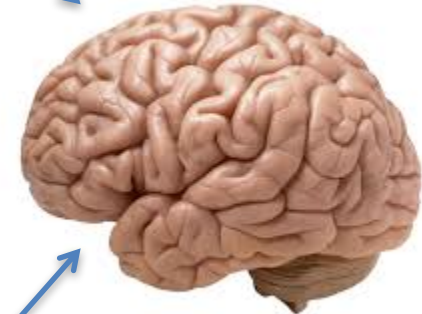
Low-latency, deeply programmable, “sliced” local cloud

A very simple case

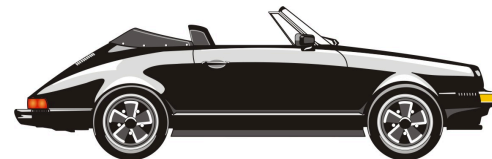
Why not use the knowledge you have ?



I know where I'm going

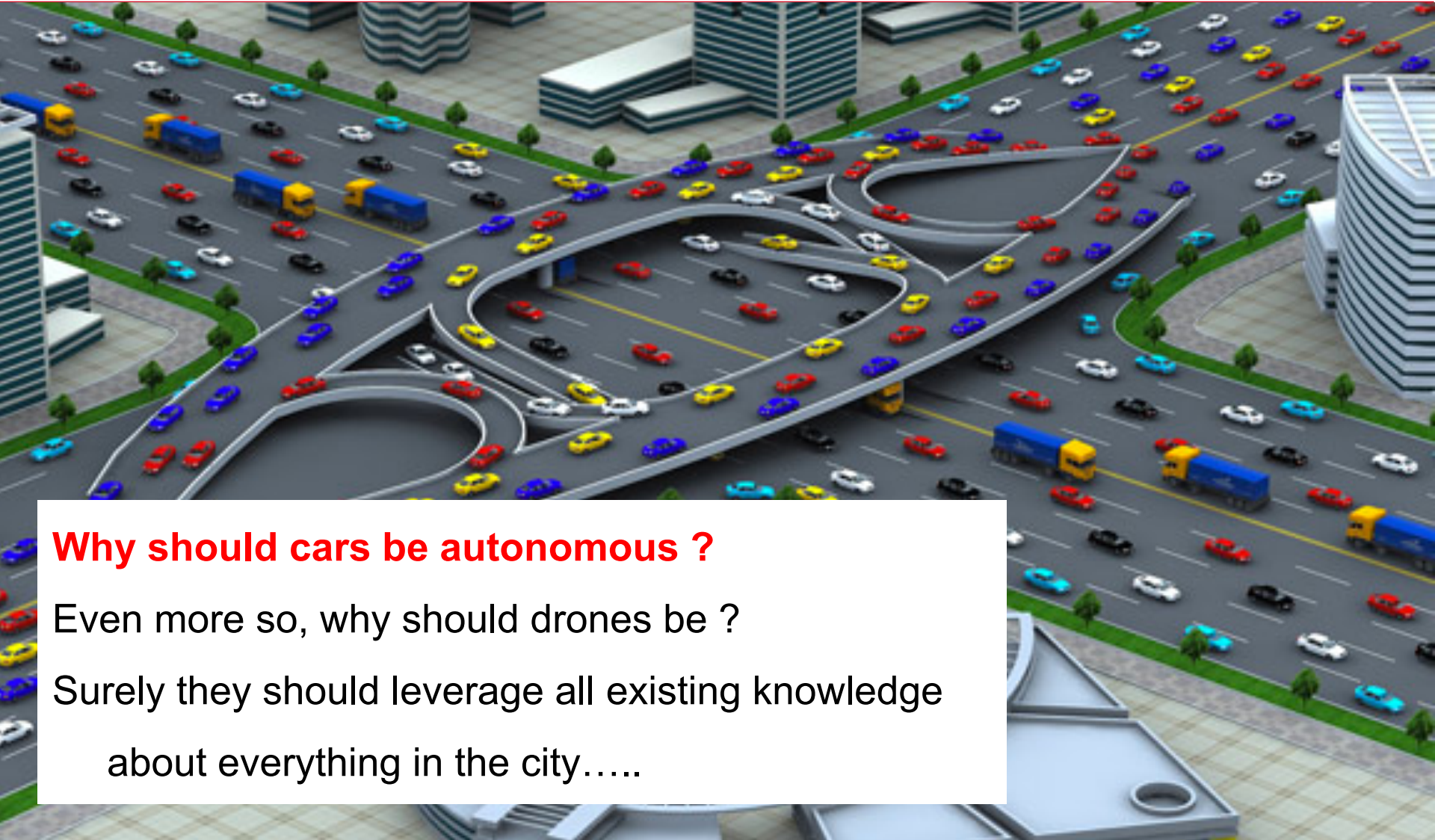


Cloud scheduling wireless assets / handoff



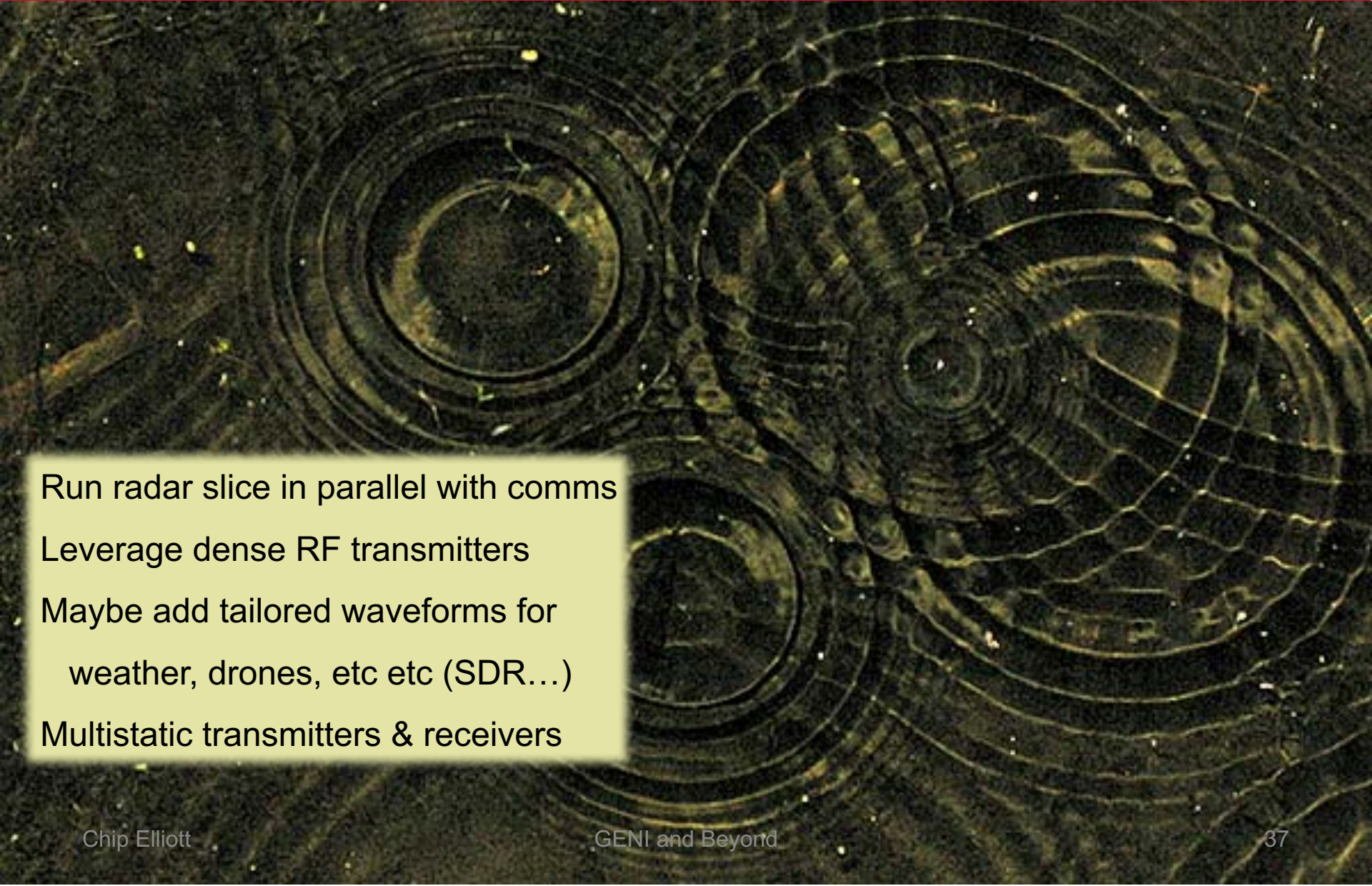
I know where I'm going

City-wide traffic orchestration?



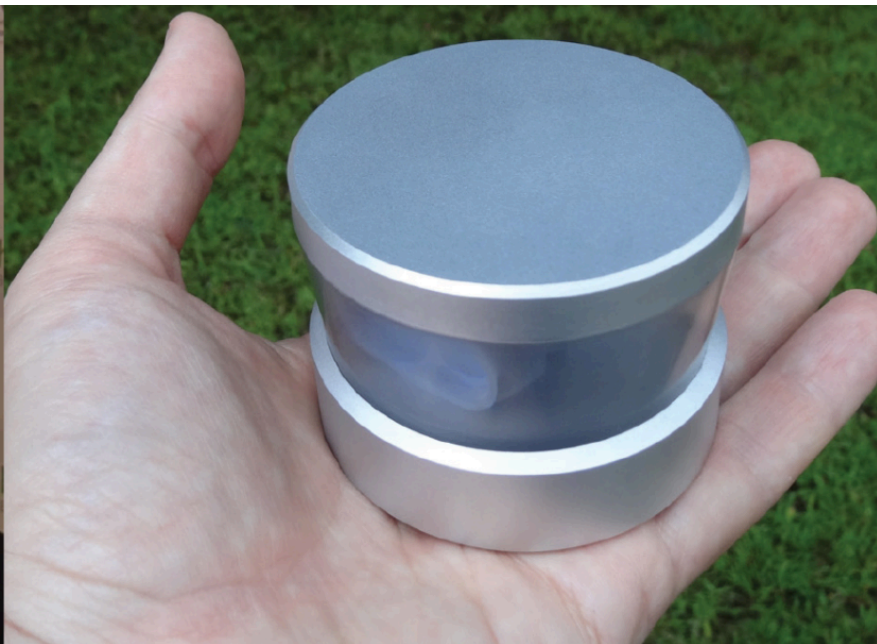
Why should cars be autonomous ?
Even more so, why should drones be ?
Surely they should leverage all existing knowledge
about everything in the city.....

Can every city get, as a service, a realtime, distributed radar system ?



Run radar slice in parallel with comms
Leverage dense RF transmitters
Maybe add tailored waveforms for
weather, drones, etc etc (SDR...)
Multistatic transmitters & receivers

Extremely fine-grain realtime sensing ?



- Lidar on every car ?
- Projected cost: \$250 / unit
- Current Velodyne stats
 - 120m range, < 2cm accuracy
 - 64 channels (emitter/receiver pairs)
 - 2.2 Million points per second
 - About 100 Mbps data stream

- What if we harvested / pooled all those “data torrents”?
 - Many looks at everything near a road (many cars, many angles)
 - Continuous, realtime infrastructure monitoring
 - Measuring weather and climate change (watch leaves)
 - Counting cars at walmart
 - Realtime RF channel models (e.g. leaves again)
 - Synthetic data for those windows

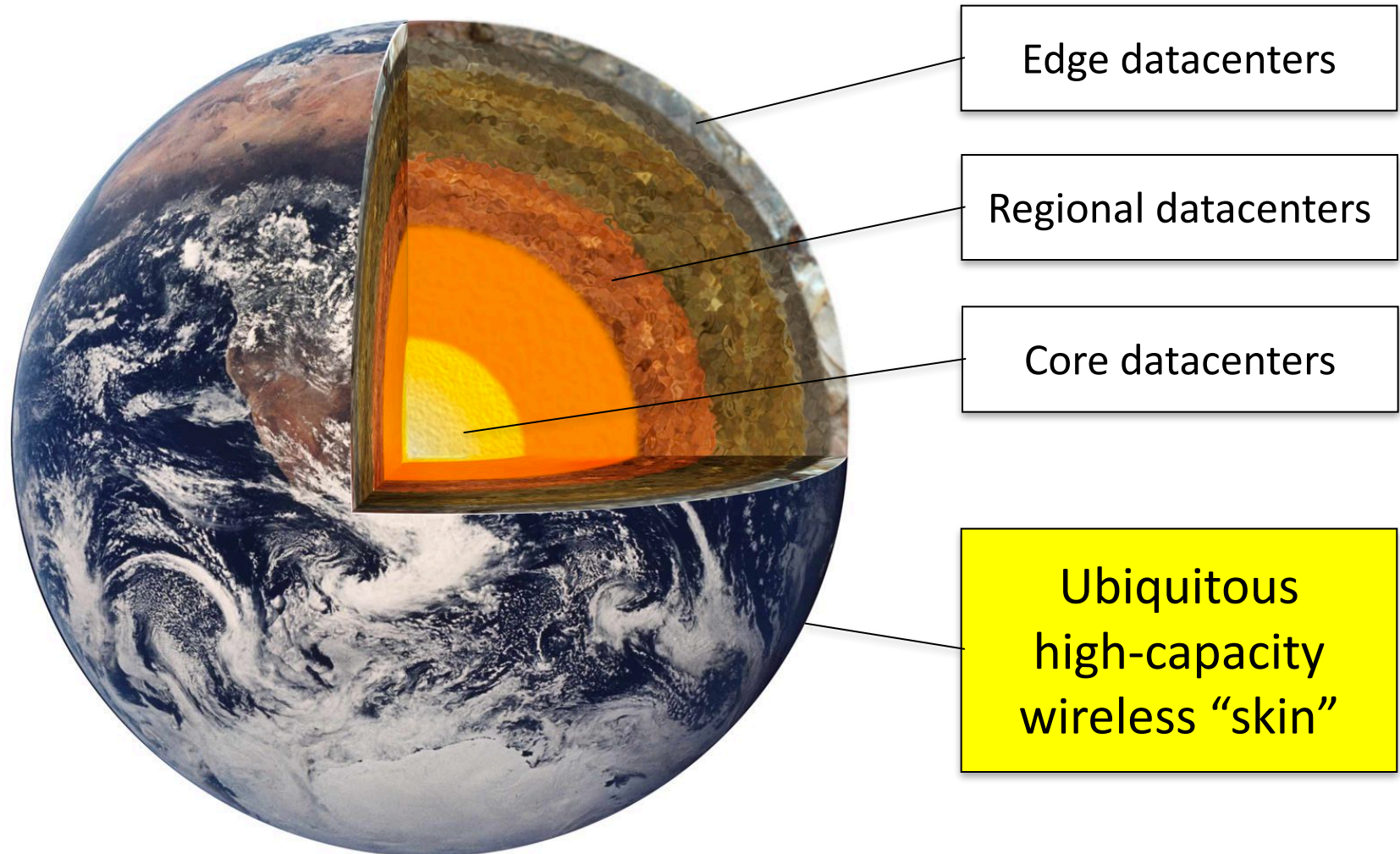
Outline

- We're moving beyond the Internet
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The best way to predict the future is to invent it

When everything is the cloud, Wireless is the Cloud's Skin



Summary

- These are **interesting times!**
- A **very deep transformation of the Internet** is now underway
- **And you are perfectly positioned** to drive the change

Be ambitious !

