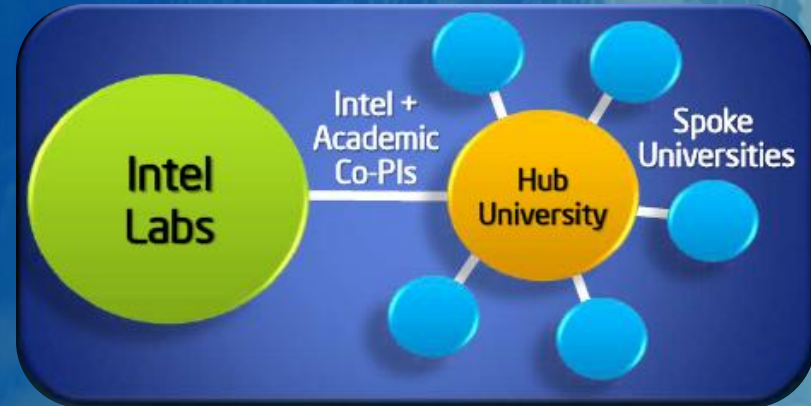# The Intel Science & Technology Center for Cloud Computing

Center Vision and Research Overview

August 3, 2011

Intel Science and Technology Centers (ISTCs)

- ISTCs funded for 3+2 years and span multiple institutions
- Encourage collaboration among the best researchers in the field
- Four Intel funded researchers per center work on-campus
- Encourage collaboration between Intel and academia
- Public domain IP and open source software increase impact

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ISTCs Announced To Date

Visual Computing
Stanford University
January 2011

Secure Computing
UC Berkeley
June 2011

Cloud Computing
Carnegie Mellon University
August 2011

Embedded Computing
Carnegie Mellon University
August 2011

...with more on the horizon

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The Intel Science and Technology Center for *Cloud Computing*

Intel PI

Academic PI

Phil Gibbons
Intel Labs
Principal Researcher

Greg Ganger, CMU
Stephen J. Jatras Professor of
Electrical and Computer Engineering

Clouds on the Horizon: by 2015...

More Users

More Devices

More Data

>1 Billion More Netizen's[1]

>15 Billion Connected Devices[2]

>1 Zetabyte Internet Traffic[3]

More Energy?

Today's Technology Would Require Building **45 New Coal Power Plants** to Support 2015 IT Infrastructure[4]

More Costs?

BAIN & COMPANY

IT will spend ~**$2T** on deployment & operations thru 2015[5] unless smarter infrastructure radically simplifies management of virtualized environments.

Internet and device expansion drives need for cloud innovation

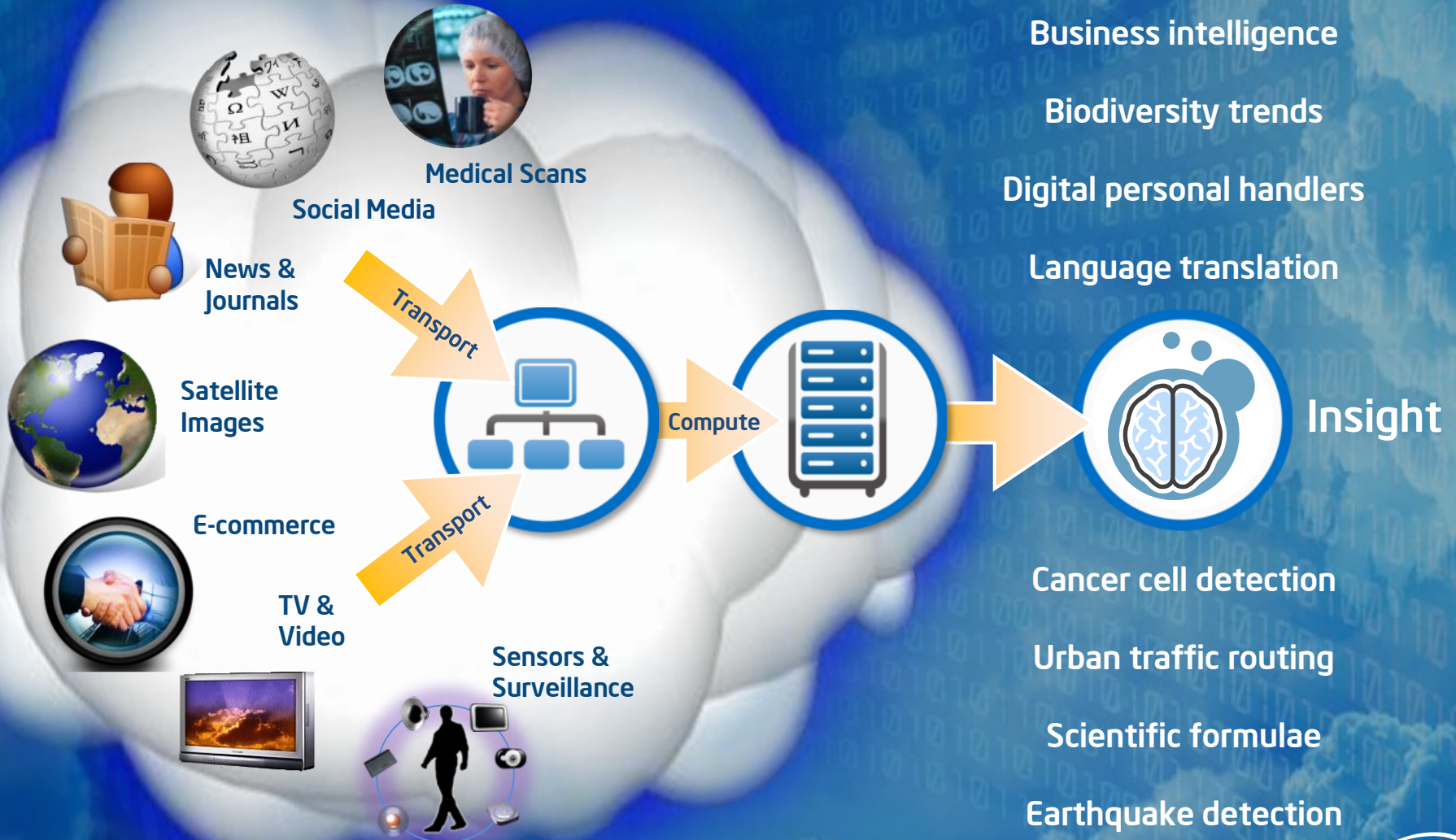1, IDC "The Internet Reaches Late Adolescence" Dec 2009, extrapolation by Intel for 2015
2. ECG "Worldwide Device Estimates Year 2020 - Intel One Smart Network Work" forecast
3. http://www.cisco.com/assets/cdc_content_elements/networking_solutions/service_provider/visual_networking_ip_traffic_chart.html extrapolated to 2015
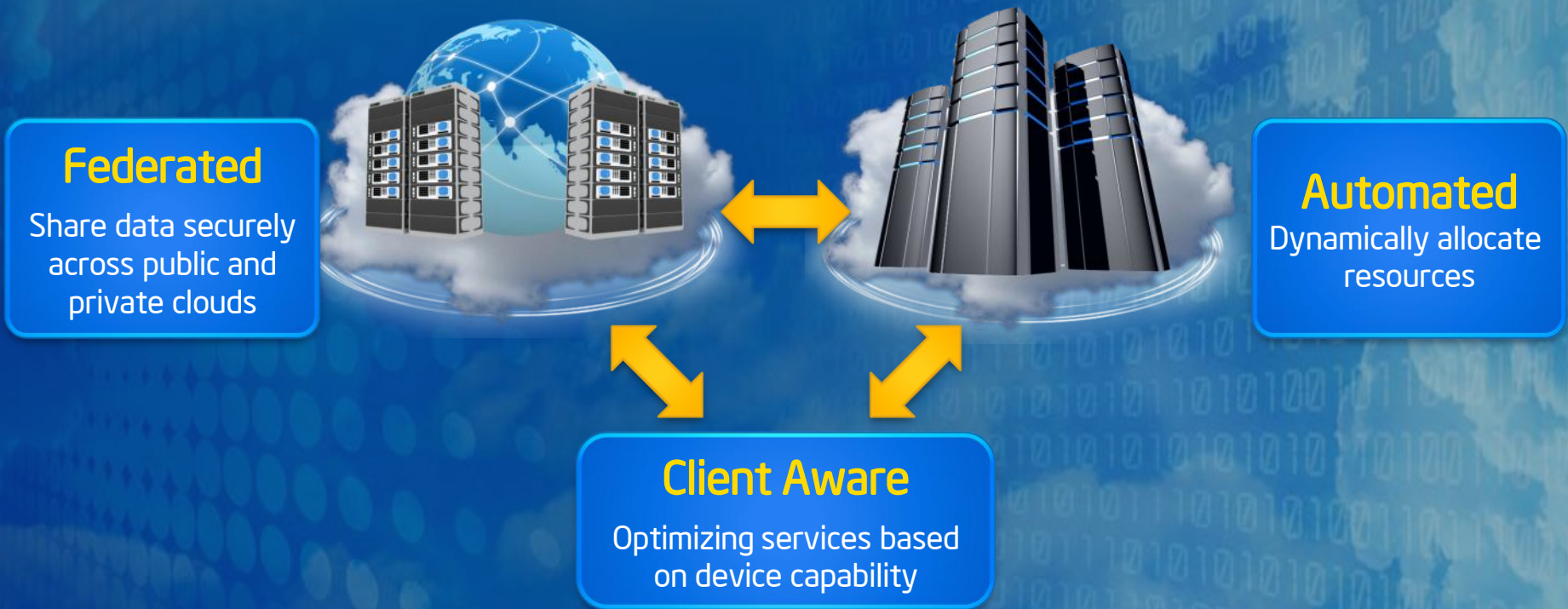4. Intel projection. See ISTC-CC whitepaper at intel.com/go/istc
5. Intel commission analysis with Bain Consulting. See ISTC-CC whitepaper at intel.com/go/istc

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Opportunity: Channel Info into Insight

Social Media

Medical Scans

News & Journals

Satellite Images

E-commerce

TV & Video

Sensors & Surveillance

Transport

Transport

Compute

Insight

Business intelligence

Biodiversity trends

Digital personal handlers

Language translation

Cancer cell detection

Urban traffic routing

Scientific formulae

Earthquake detection

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Intel Cloud 2015 Vision

Federated
Share data securely across public and private clouds

Automated
Dynamically allocate resources

Client Aware
Optimizing services based on device capability

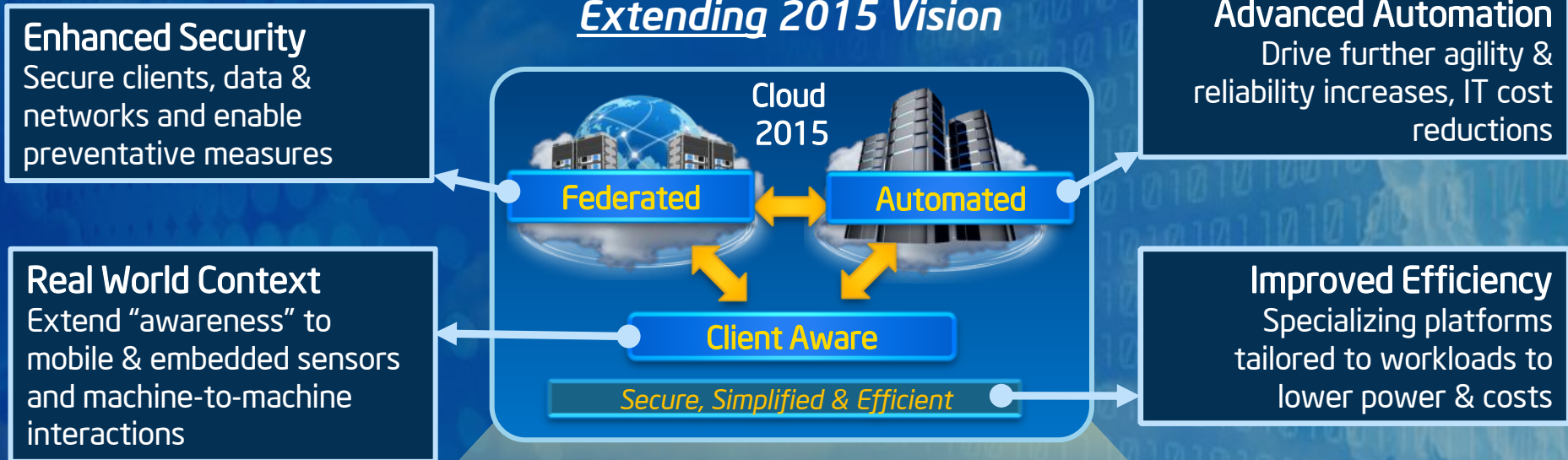## To achieve vision and beyond, make the cloud more:

Secure
Reduce risk, increase compliance, manage hybrid clouds

Efficient
Optimizing technologies to decrease energy, human and physical asset consumption

Simplified
Simplify data center operations to reduce cables, complexity and cost

7

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Beyond Cloud 2015: R&D for 2020+

Enhanced Security
Secure clients, data & networks and enable preventative measures

Real World Context
Extend "awareness" to mobile & embedded sensors and machine-to-machine interactions

Extending 2015 Vision

Cloud 2015

Federated ↔ Automated

Client Aware

Secure, Simplified & Efficient

Advanced Automation
Drive further agility & reliability increases, IT cost reductions

Improved Efficiency
Specializing platforms tailored to workloads to lower power & costs

Expanding to broader demands for the future cloud

"Big Data" Insights
Derive business, scientific, & social insight from global knowledge

Distributed
Enabling compute to move wherever it is needed and apps that span cloud, client and edge.

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Choosing Carnegie Mellon

EXPERTISE

- **Prof. Greg Ganger:** Director of Parallel Data Laboratory, chosen to testify before congressional hearing on the benefits and risks of moving federal IT to the cloud.

- **Prof. Garth Gibson:** IEEE R.B. Johnson Award recipient for seminal work on RAID, leader in PRObE effort

- **Prof. David Andersen:** Leader in use of lightweight nodes for improving data center energy efficiency

EXPERIENCE

- **Data Center Observatory:** >450 nodes for research
- **Open Cirrus:** network of 15 institutions including Carnegie Mellon, Georgia Tech, and Intel

ENVIRONMENT

- **Notable collaborative research efforts:** integration of optical networking in the data center, power-proportional cluster file systems, and data center energy-efficiency improvement

- **10 year history of successful Intel-CMU collaboration**

Data Center Observatory

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ISTC-CC Research Agenda

| RESEARCH PILLAR	TARGET BENEFIT
Specialization	▪ Dramatic efficiency to lower power & increase productivity
Automation	▪ Agility, efficiency & robustness increases, IT cost reductions
Big Data	▪ Business, scientific, and social insight from huge bodies of data
To the Edge	▪ Richer interactive experiences via smarter devices & edge-locality
Security	▪ Secure clients, data & networks and preventative measures

Newest ISTC for Cloud Computing

Recent ISTC for Secure Computing

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Specialization

Lightweight nodes
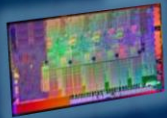
Many-core
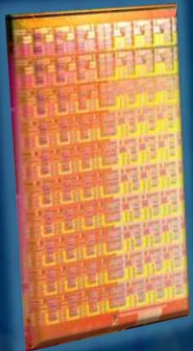
Phase-change Memory (PCM)

- Specialization is fundamental to efficiency
  - No single platform best for all application types
  - Called **division of labor** in sociology (see also, bees)

- Cloud computing must embrace specialization
  - As well as consequent heterogeneity and change-over-time
  - Stark contrast to common data center practice

- Sample research activities
  - Specializing via lightweight nodes (e.g., for key-value stores)
  - Specializing via many-core (e.g., for visualization)
  - Exploring impact of new technologies (e.g., PCM)
  - Programming models for adapting to specializations

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Automation

- **Automation is crucial to cloud reaching potential**
  - Needed yesterday, but cloud makes it worse
    - Larger scale, more varied app mixes, specialization,...
- **Sample research activities:**
  - New techniques for diagnosing problems
    - Including new instrumentation, algorithms, and approaches
  - More robust software upgrade management
    - Via runtime correctness checking at scale
  - Resource allocation and scheduling, in face of...
    - Multi-faceted goals: availability, efficiency, predictability, ...
    - Diverse mixes of workloads (type, duration, priority)
    - Mixes of specialized computing platforms

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Big Data

Customer Database

~600 TB

HD Internet Video

12 EB/yr

Particle Physics

300 EB/yr

- Extracting insights from large datasets
  - A.k.a. "analytics" or "data-intensive computing" (DISC)
  - Becoming critical in nearly every domain
    - and likely to dominate cloud data centers of the future
- Need new programming/execution models
  - For productivity, efficiency, and agility
- Sample research activities
  - New frameworks for advanced machine learning
  - Tools for debugging DISC programs (inc. performance)
 - Usable high-ingest cloud data management

10^6 MEGA   10^9 GIGA   10^12 TERA   10^15 PETA   10^18 EXA

To the Edge

- Edge devices will participate in cloud activities
  - Serving as bridge to physical world (sense/actuate)
  - Enhancing interactivity despite location / connectivity

- Need new programming/ execution models
  - For adaptive cloud + edge cooperation

- Sample research activities
  - Adaptive cloud-assisted mobile computation
  - Mitigating reliance on limited uplink bandwidth
  - Decentralized, edge-local cloud architectures

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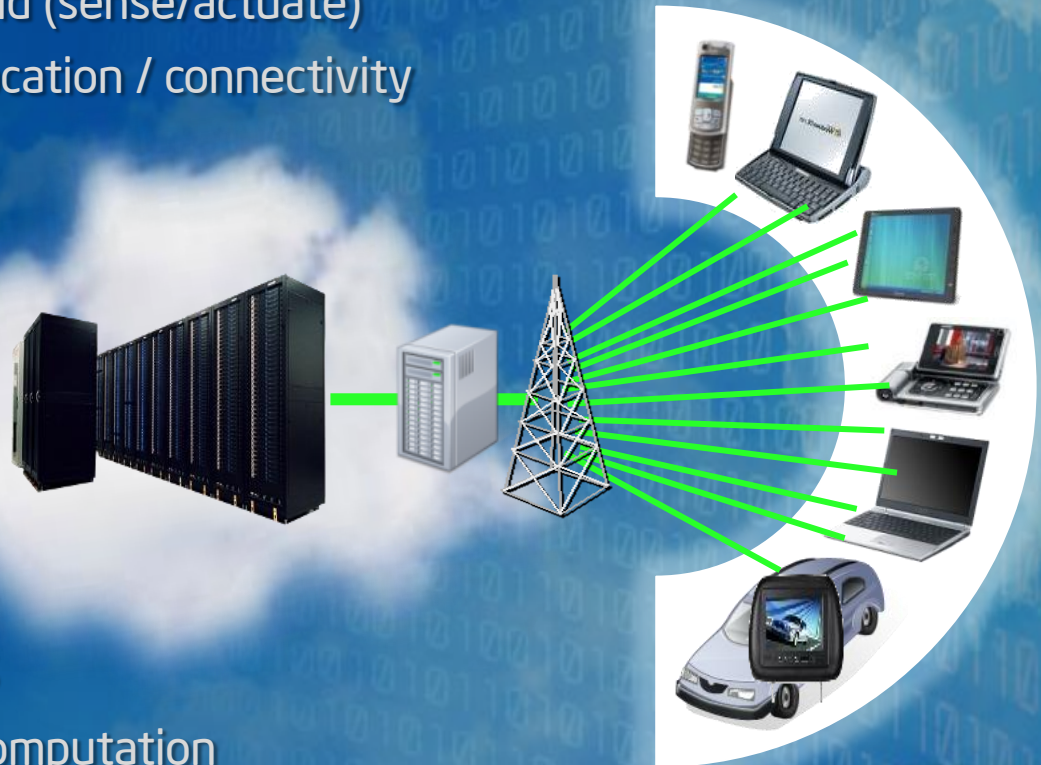
Collaboration, outreach & shared testbeds

- ISTC-CC will be open and collaborative
  - Extensive collaborations among initial participants
  - engaging others in vibrant, growing community

- Connecting with others on broader agenda
  - Ex: future cloud apps (e.g., visual and embedded ISTCs)
  - Ex: cloud security (e.g., ISTC-SC and CyLab)

- Shared testbeds play a crucial role
  - Engages cloud application researchers
  - Enables capture of usage patterns, case studies, etc.
  - Example: OpenCirrus (x3)

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Summary

- ISTC investments extend and expand Intel's Cloud vision w/ insight from academic thought leaders

- Innovating in automation & specialization to improve efficiency, reduce power, lower costs

- Breaking down client/cloud/edge barriers to make the cloud more pervasive, responsive, and useful

- Improving 'Big Data' analysis to spur business, scientific, and social breakthroughs

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