Collaborative Innovation for ICT-Enabled Future Society Solutions

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NEC Corporation
Tech drives Innovation, Innovation drives Tech

Role of Apps playing the central role to ICT’s evolution


IT System
- Main Frame
- Client / Server
- Web System
- Cloud Computing

Centralized
Distributed

Technology
- Work Station
- PC
- Internet
- Broadband
- Mobile Device

Innovation

EC  SNS  XaaS...
Cloud Application Landscape

Cloud application is expanding from consumer services to enterprise and to society.

- **Public Cloud**
  - Web Search
  - EC
  - Storage
  - SNS

- **Private Cloud**
  - Groupware
  - CRM
  - BI
  - SCM
  - Finance
  - Human resource

- **Society**
  - Energy
  - Disaster Recovery
  - Safety

(Vendor list: based on IDC 2013)
3.11 Tohoku Earthquake and Tsunami

- Communication services were down
  - 1,000,000 landlines outage
  - 14,800 mobile base stations damaged
- Internet was not completely dead, but at a very limited quality

- Google: “Google Person Finder”
  - Safety check service was launched in 1h 46min after the earthquake

- Twitter
  - Played a critical role in sharing local info (food, doctor, blackout, etc.)
  - New registration world-wide jumped up by 25% on 3/12
  - Local governments relied on twitter for info transmission

Source: www.47news.jp

Source: NTT docomo
3.11 Impact on Enterprise / Public IT systems

IT customer’s mindset was changed

- **before:** On premise in convenient large cities
- **after:** Cloud in remote / distributed data centers
  - ✓ Electricity saving became more important in view of power shortage and rise in electricity price
  - ✓ Disaster recovery / BCP was revised to be viable

Government started twitter information services as a social infrastructure

Source: www.47news.jp
Big Data, IoT/CPS as booming trend in IT Apps

Discovering value from Big Data is becoming the mainstream
- e.g. CDO (Chief Data Officer) as an emerging trend

IT app. of IoT/Cyber-Physical System. is also increasing rapidly
- 12x growth from 2009 to 2020, $300B in 2020

Big Data technology and services revenue

2011-2016 CAGR 31.7%

12 times growth

(Source: IDC 2013, Gartner 2013)
21st Century is the Age of Cities

Cities are swelling, with rapidly increasing populations and problems.

Half of the world’s 7 billion people live in cities

In 2050, 70% of the world’s 9 billion people will live in cities

Why do people gather in cities?

Job and Infrastructure

Where people gather, industries prosper, economy grows, allowing investment in social infrastructure, attracting more people and more industry…

Growth of world’s urban and rural populations (UN statistics)

1970: 1.3b urban, 2.4b rural
2010: 3.5b urban, 3.4b rural
2050: 6.4b urban, 2.8b rural

If such a positive spiral fails, people leave and the city decay.
Perspective I want to share is on collaboration

Today, importance of “collaboration” is of no doubt for innovation, and not new

Still, I think it makes sense for ICNC colleagues to take a look at NEC’s research as a case study of “collaboration for innovation”

because ……
Comparing NEC’s Research and ICNC

There is a similarity in the broad coverage of technical areas, IT and NW, from PF to APP.

<table>
<thead>
<tr>
<th>Application</th>
<th>Cloud &amp; Networking platform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Processing for Communications</td>
<td>Green Computing, Communications and Networking</td>
</tr>
<tr>
<td>Internet Services and Applications</td>
<td>Data Storage Technologies and Applications</td>
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<tr>
<td>Cloud Computing and Big Data</td>
<td>Cognitive Computing and Networking</td>
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<tr>
<td>Data Analytics</td>
<td>Wireless Networks</td>
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<td>Wireless Ad Hoc and Sensor Networks</td>
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<td>Mobile Computing and Vehicle Communication</td>
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<td>Communications and Information Security</td>
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<td>Network Algorithms and Performance Evaluation</td>
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<td>Communication QoS and System Modelling</td>
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<td>Thermal Management, Battery, EMS</td>
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<tr>
<td></td>
<td>Machine Learning</td>
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<td>Natural Language Processing</td>
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<tr>
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<td>Video / Speech Recognition</td>
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<td>Signal Processing, Vibration Sensor</td>
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<td>Parallel / Distributed Processing</td>
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<td>Data Management</td>
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<td></td>
<td>SDN / Open Flow, NW Virtualization</td>
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<tr>
<td></td>
<td>Wireless NW, Optical NW</td>
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<td></td>
<td>Cyber Security</td>
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<td>Privacy Protection, Encryption</td>
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<td>System Modeling</td>
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<td></td>
<td>Cloud Service Management</td>
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</table>

There is a similarity in the broad coverage of technical areas, IT and NW, from PF to APP.
NEC Mid-term Management Plan 2015

Realization of an affluent and equitable society which makes efficient use of resources and whose members are safe and personally secure

Solutions for society

- Supporting the advancement of social infrastructure and systems throughout the world via ICT
- Create new business models with the understanding that social problems provide an opportunity for growth

Transformation into Social Value Innovator
Social Value Creation via ICT

Collection of large-scale data
- Diverse sensors
- Surveillance cameras
- Smart devices
- Accumulated data

Analysis and prediction
- Invariant analysis
- Heterogeneous mixture learning
- Facial image analysis
- Behavior analysis
- Textual entailment recognition

Solution of social issues

Diverse sensors and human interface technologies
- From the seafloor to outer space

High-performance/high-reliability core IT technologies

Next-generation network technologies
- Network virtualization
- Cyber security
- SDN: Software-Defined Networking

Leveraging information captured by our unique and highly competitive ICT assets to become a social value innovator

* Rated as No. 1 among organizations participating in an evaluation task organized by the U.S. National Institute of Standards and Technology (NIST)
Perspective I want to share is on collaboration

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because ……
NEC’s direction has a lot to do with the general ICT trend

- Technology evolution becoming more innovation-driven (i.e. app driven) than performance driven
- IT apps expanding from consumer to enterprise, and to society
- For IT apps, central value to users is migrating towards value extraction from Big Data (by analytics)
- Another booming app field is for real world/physical issues (Cyber Physical Systems, Internet of Things)
# Focused Area of NEC Research

## Focused area

<table>
<thead>
<tr>
<th>Big Data</th>
<th>Real World Recognition</th>
<th>Data Analytics</th>
<th>Big Data Processing</th>
<th>SDN (Software-Defined Networking)</th>
<th>Security</th>
<th>SI Engineering</th>
<th>Smart Energy</th>
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<tbody>
<tr>
<td></td>
<td>Video / Speech Recognition</td>
<td>Machine Learning</td>
<td>Parallel / Distributed Processing</td>
<td>Open Flow, Network Virtualization</td>
<td>Cyber Security</td>
<td>Model-based System Integration</td>
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</tbody>
</table>

- Vibration Sensor Natural UI
- Storage Embedded System
- Wireless Network Optical Network
- Human Centered Design
- Low Power Circuit
R&D directions for future social value innovation

Focus on seven research areas towards advancement of social infrastructure

- Energy/Climate
- Agriculture
- Manufacturing
- Distribution/Logistics
- Transportation
- Disaster prevention/Security
- Healthcare

Big Data

- Real World Recognition
  - Expansion of scope for visualization

- Data Analytics
  - Prediction and forecasting

- Big Data Processing
  - Real-time

- SDN
  - Individualized optimization

- Security
  - Measures to reduce information leakage risks

- SI Engineering
  - Customization and downsizing

- Smart Energy
  - Energy use optimization

- Measures to reduce information leakage risks
  - Defense from unknown attacks

- Global optimization
  - Facilitation of global deployment

- Shift to convenience for individuals/society
  - Optimization & Control
Real World Recognition
Face Recognition / Behavior Recognition

NEC’s technological differentiator in public safety solution business

Global No.1 face recognition technology

- Achieved high recognition rate for even faces with shadows in bad illumination conditions
- Won the first prize with a significant difference from others in the NIST global benchmark (MBE)

- Achieved about one-tenth the error rate of competitors.

Human trajectory analysis using multiple cameras

- Estimates person’s real world location with high accuracy (about 25 cm)
- Makes it possible to analyze person behavior, to detect intrusions and suspect behaviors

Source: MBE report issued by NIST

Achievement of Match error rate

<table>
<thead>
<tr>
<th>Company</th>
<th>Error Rate</th>
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</thead>
<tbody>
<tr>
<td>NEC</td>
<td>0.3%</td>
</tr>
<tr>
<td>X</td>
<td>2.5%</td>
</tr>
<tr>
<td>Y</td>
<td>3.4%</td>
</tr>
<tr>
<td>W</td>
<td>4.1%</td>
</tr>
<tr>
<td>T</td>
<td>4.4%</td>
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<tr>
<td>Z</td>
<td>7.1%</td>
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<td>P</td>
<td>9.2%</td>
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</table>

Match error rate

- Good (False rejection rate @ 0.1% of false acceptance rate)
- Surveillance video
- Results of person area extraction
- Person trajectories projected on the floor map
Benefits:
Face recognition Implemented at the driving lanes to streamline operation procedures and minimize manual operations
Universal Studios Japan

Your Face can be a pass: An ultra user friendly entry system

- Provide a way to prevent spoofing of annual pass
- Cost reduction of pass card issuing process
- Visitors enjoy it as a new entertainment

Universal Studios Japan™: Access Control System (Japan)
Real World Recognition: Research Direction

Tech Challenge: Acquisition and analysis of real-world data through the understanding of diverse meanings

Visualization of signs of future events

- Emotion understanding
- Behavior recognition
- Face recognition
- Recognition of entire scenes

New business creation

- City wide-area surveillance and management
- Efficient social infrastructure maintenance
- Smart store management

Depth of understanding

Intention

Behavior

Appearance

Individual

Entirety

Scale of understanding
Crowd Behavior Analysis for Anomaly Detection

Early abnormal event detection of crowd in a dense situation
Analysis by using crowd patches without individual recognition

Security cameras

Incidents and their signs

Spread out over surrounding crowds as abnormal crowd behaviors

Crowd behavior analysis

Over-crowding  Crowd running  Surrounding  Staying crowd
[Video demo] Crowd Behavior Analysis (1)

- Detection of people rushing

- Detection of overcrowding
[Video demo] Crowd Behavior Analysis (2)

- Detection of people stopping and hanging out
- Detection of people surrounding an accident
Singapore Safe City Test Bed

Supported by Singapore government, Economic Development Board (EDB)

Intent of Test Bed
To develop new capabilities to keep Singapore safe and secure.

Scope
Setting up test beds to enable different government agencies to integrate and analyze data collected from existing sensors and network systems using advanced analytic and information sharing tools.

Source: EDB’s Home Page
To build a complete, end-to-end inter-agency collaboration infrastructure that uses cutting-edge technologies, such as advanced data analytics, risk analysis and relationship modeling, to help multiple agencies understand and correlate information from various sources as well as to optimize resource deployment on the ground.

System concurrently tries to detect various incidents...

- Snatch thief
- Fighting
- Overcrowding
- Crowd dispersal
- Intrusion
- Boundary crossing
- Collapsed person
- Missing object
- Abandoned object
- Loiterer

And more...

<table>
<thead>
<tr>
<th>Year</th>
<th>Requirement</th>
<th>Development &amp; Integration</th>
<th>Live Testing</th>
<th>Evaluation &amp; Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>2014</td>
<td>12</td>
<td>7</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

EDB Economic Development Board
SPF Singapore Police Force
NEA National Environment Agency
PUB Public Utility Board
SCDF Singapore Civil Defence Force
LTA Land Transport Authority
MHA Ministry of Home Affairs

World Cities Summit 2014 ▲
Data Analytics
R&D Direction to Maximize Value for Society/Customer

3. Scaling beyond human capability

1. Visualization of data that human cannot see

2. Finding rules that human cannot capture
Science-based approach to create state-of-the-art analytic engines enabling real-world analysis from complex and huge-volume data
Data analytics engines for sustainability of social infrastructure
Heterogeneous Mixture Learning

Automatically discovers “hidden rules” by finding the optimal way to partition data without experts’ hypotheses

"How many kinds of data mix?” “How should we partition?” “What model does each data have?”, These are all unknown.

× Conventional methods needed a lot of trial & error and relied upon on the experts’ hypotheses

Heterogeneous Mixture Learning (NEC original)

Using “FAB Inference”
(FAB: Factorized Asymptotic Bayesian Inference)

- Particularly useful for social solutions due to
  ✓ suitability to real-world problem (i.e. mixed data)
  ✓ applicability to wide range of problems (i.e. versatility)
Customer Collaboration: Predict Power Consumption of Building

**Heterogeneous Mixture Learning (Based on 3 patterns prediction)**

- **Learning period**
- **Predicting period**

- Average error 2.7%

**Conventional Method (Based on manual partitioning)**

- **Learning period**
- **Predicting period**

- A large margin of error occurs whenever rules change.
- Average error 5.8%
Customer Collaboration: Sales Prediction at Retail Stores

HML automatically extracts various factors affecting sales of each item
- The days of the week, weather, temperature, popularity trend, …

Makes highly accurate sales forecast and optimizes the ordering work

- Human driven approach
  - Depend on past human experiences and knowledge
  - Biased by human factor
  - Applicable to limited items

- Data driven approach
  - Taking into account various data
  - Unbiased by human factor
  - Applicable to all items in all stores

Minimizes both abandonment loss and opportunity loss

Learning

Prediction

Actual

Prediction

Detecting Anomalies in Large Physical Systems

Thousands of observation points

Time series observation data

Before
- Risk of infrastructure deterioration becomes more serious
- Abnormality detection relies on experts

SIAT (System Invariant Analysis Technology)


After
- Rapid abnormality detection and prevention of failure by SIAT
- Earlier detection than expert
SIAT: System Invariant Analysis Technology

Automatic modeling of the entire physical system from correlations among the sensor data by using “invariance” relationship
- Just from the observed data. Domain-specific knowledge not required!

Early anomaly detection achieved by comparing current data with the ones predicted from the model to determine if unusual event is occurring
- Much earlier than threshold-based detection

Visualize normal state

Unusual movement

Anomaly detection

Two observation data in the invariant relationship

Detection time shorter by 1/20 than human (expert) ability
At the Shimane Nuclear Power Station, we confirmed the effectiveness of a “large-scale plant failure sign monitoring system” using Invariant Analysis (with The Chugoku Electric Power Co., Inc.).

- Number of sensors per reactor: 3,500
- 100 pcs. of data per sensor per second

Discovering anomalies from correlations in 3,500 x 3,499 sensor combinations

- Improved the accuracy of warning sign monitoring through close collaborations between the customers’ power plant operation experts and NEC’s analytic experts
Data analytics for improving internet services

--- REAL TIME predictive analytics for real time services ( of real time video streaming )
Research Background

- Rapid growth of mobile data traffic (CAGR 66%)
- Keeping the quality of communication services under the explosive increase in network traffic is a big challenge

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**Mobile data traffic [1]**

<table>
<thead>
<tr>
<th>Year</th>
<th>mobile data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>0.5 EB/month</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>1.0 EB/month</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>1.5 EB/month</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>2.0 EB/month</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>3.0 EB/month</td>
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<tr>
<td>2017</td>
<td>4.0 EB/month</td>
<td></td>
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</tbody>
</table>

\[ \times 13 \]

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**Mobile application traffic share [2]**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Application</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>YouTube</td>
<td>31%</td>
</tr>
<tr>
<td>2</td>
<td>HTTP</td>
<td>14%</td>
</tr>
<tr>
<td>3</td>
<td>SSL</td>
<td>9%</td>
</tr>
<tr>
<td>4</td>
<td>MPEG</td>
<td>9%</td>
</tr>
<tr>
<td>5</td>
<td>Facebook</td>
<td>7%</td>
</tr>
</tbody>
</table>

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Conventional Approach

Network-layer approach

- Each network operator controls its own network – QoS
- End-to-end quality is, however, uncontrollable because the Internet is a cluster of various networks.

The Internet = a cluster of multiple networks

No one knows end-to-end quality

Each QoS is not more than local optimization
Service-level Communication Optimization

End-to-end approach

- Understanding end-to-end network conditions and improving the communication quality “on the application layer”
- Communication control based on prediction and estimation of the network characteristics (throughput, delay, loss, etc.)

Adaptive communication control based on prediction and estimation

Effective and high-quality e2e communications

Application on a server

Application on a client

Application layer

Network layer

Servers

Networks

Clients

Core Technologies

Prediction, estimation, and adaptive communication control using a set of REAL TIME analytics

Network and traffic estimation\rightarrow\leftarrow\text{Rheology and hydromechanics}

Network prediction\leftarrow\text{Financial engineering}

Communication control\leftarrow\text{Robust and optimal control}

**Prediction & Estimation**
- Throughput
- Bandwidth
- Terminal condition
- Packet loss
- Congestion
- Delay

**Adaptive communication control**
- Apply to application requirements
- Adaptive to network conditions

Monitoring\rightarrow\text{the Internet (black box)}\rightarrow\text{Physical network}

Mobile\rightarrow\text{Fixed}\rightarrow\text{Public Wi-Fi}
Need for Estimation and Prediction

Need for estimating parameters that cannot be observable at an end host

Need for predicting fluctuating parameters for proactive communication control

The world’s top estimation and prediction technologies

- 40x quicker, 100x lighter, and 3x more accurate end-to-end available bandwidth estimation
- The world’s first practical throughput prediction, over 90% accuracy for the next 1 minute
Throughput Prediction

Unit root test
Status: Stationary

Stochastic diffusion
Expectation

Prediction accuracy 80.6%
Statistics: $x_0 = 3.37, \sigma = 0.535, \sigma_2 = 0.468, \hat{\alpha} = 2.18, \hat{\delta} = -0.528$

FPS: 6.211180
The throughput prediction tells the worst case scenario.

Controlling the video bitrate according to the worst case scenario avoids interruption, while keeping the bitrate high.

Adaptive video streaming leads to no interruption and high quality.
[Video demo] Adaptive Video Streaming

250kbps

250kbps

250kbps

250kbps
Future Direction: Advanced communication optimization

Federation with SDN is a key approach to heavier traffic and more latency-critical applications.

- Video delivery
- Web access
- Cloud storage
- Social network
- Voice

Prediction & Estimation

Understand the future network conditions for real-time applications.

Adaptive Communication Control

Proactive about the future conditions and fulfill the application requirements.

SDN Controller

Federation

Virtual Networks

Mobile Networks

Fixed Networks

Wi-Fi
Technology Value

Achieves better communications environments
Achieves ecosystem among the stakeholders

Telco

WIN
Improves efficiency of networks

WIN
Service provider
serves more users

WIN
User
obtains higher experience

Advanced communication optimization
What is SDN (Software-Defined Networking)?

SDN refers to dynamically controlling networks using software and its architecture.

**Past**
Control and communication processing were tied together within single equipment.

**Future**
Network control and communication processing are separated.
Communications processing is dynamically controlled by software.

- **Separation**: Network control and communication processing are separated.
- **Control**: Communications processing is dynamically controlled by software.
- **Future Equipment**: General-purpose server and dedicated equipment with network control function.
- **Past Equipment**: Dedicated equipment with network control function.

SDN refers to dynamically controlling networks using software and its architecture.
SDN Application Example

Achieves easy-to-use online services even under heavy internet access

Present

Using SDN

Oh, no! Cannot access! The sale is almost over!

I got it!
SDN Application Expanding

Present

Mainly focusing on virtualizing data center networks

Future

- Expanding the applicable market:
  - Data centers infrastructures
  - Enterprise network
  - Telecom carriers infrastructures
Solution menu was established based on our SDN products, and case studies with customers ongoing.
In addition to the data center market, our solution is also deployed to enterprises, public agencies and telecom carriers*1

<table>
<thead>
<tr>
<th>Market</th>
<th>Category</th>
<th>Solution</th>
</tr>
</thead>
</table>
| NEC Enterprise SDN Solutions | Network Optimization | •WAN Connection Optimization for Offices and Data Centers
•Office LAN Optimization |
| | Security | •Access Authentication |
| | Mobile | – |
| NEC Data Center SDN Solutions | Operation and Management | •IaaS Operation Automation Solution |
| | Consolidation | •Data Center Network Integration Solution |
| NEC Telecom Carrier SDN Solutions | Network Management | •Integrated Operations Management |
| | Network Infrastructure | •Network Virtualization
•Transport |

Products

- WebSAM vDC Automation
- UNIVERGE PF Series
- ProgrammableFlow

*1: Availability varies by region
### Past Case SDN Studies / Successful Field Tests

Implementation and successful field testing of NEC’S SDN in companies and organizations is accelerating globally.

<table>
<thead>
<tr>
<th>Market</th>
<th>Japan</th>
<th>Worldwide</th>
</tr>
</thead>
</table>
| Enterprises and Public Agencies | • Nippon Express  
• Kanazawa University Hospital  
• Minamihon Information Processing Center  
• NEC BIGLOBE  
• tv asahi corporation  
• Ministries and agencies  
• Universities  
• Transportation service industry  
• Distribution industry  
• Manufacturing industry  
• Broadcasting stations  
• Electronics manufacturers  
• Trading companies  
• System integrators | • Stanford University  
• Selerity Corp (New Jersey) |  |
| Telecom Carriers              | • NTT Communications (Biz Hosting)                                    | • GenesisHosting (Chicago) *  
• Tervela (New York) *  
• Telefónica (Spain)  
• Portugal Telecom (Portugal)  
• Myanmar Posts and Telecommunications |  |

NEC’s SDN is being used and field tested in the operations systems of many (over 100) companies and organizations.
Network Functions Virtualization Solutions

- Use common general-purpose servers instead of purpose-built equipment for each function, to enable easy maintenance and upgrades
- Flexibly allocate multiple network function resources based on traffic demand

World’s first commercial vEPC
(EPC: Evolved Packet Core)

- High scalability
- Carrier grade performance
  Same performance as purpose-built equipment
- Uses general-purpose servers
  TCO reduced by 30-40%

Implemented in Myanmar communications infrastructure project (December 2013)

Announced Oct. 22, 2013

Example of NFV
Data forwarding and control functions on a general-purpose server

Flexibility and scalability

Completion ceremony held in Myanmar, December, 2013
Handling Emergency Situations with SDN

Increase capacity for communication tools such as email, voice calls
Test bed trail ongoing under collaboration: NEC, NTT docomo, Fujitsu

( Government project by Ministry of Internal Affairs and Communications )
SDN Solution for Kanazawa University Hospital

- Improved hospital network management efficiency to support 24/7 medical services
- Integrated all department LANs with different policies and reduced installation costs
- Provided stable networks and reduced time and labor costs required for operation management and configuration modifications

**Conventional Network**

**SDN (OpenFlow) Network**

- Electronic records
- Anesthesia dept.
- Radiology dept.

- Electronic records (Patient info)
- Anesthesia dept.
- Radiology dept.

- Network appliance pool
- Firewall
- Network pool
- Server pool
Effect of SDN Implementation in Kanazawa University Hospital

Approximately 80% of labor costs for changing network settings reduced by the implementation of SDN

Comparison of the number of man-hours required for network configuration work

<table>
<thead>
<tr>
<th>Conventional technology</th>
<th>9 man-days</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDN (OpenFlow)</td>
<td>2 man-days</td>
</tr>
</tbody>
</table>

Comparison of time taken for changing similar scale settings that actually occurred in the hospital.

Approx. 80% reduction
FlowComb: App for SDN boosting computation

Execution platform for big data analytics like Hadoop is booming.

However

Massive data movement in Hadoop leads to network congestion and degraded application performance.

Data movement and job scheduling is key for high performance.

FlowComb seamlessly integrates OpenFlow for data movement scheduling with Hadoop job scheduling.

[A.Das, C.Lumezanu, et al., HotCloud 2013]
FlowComb: Basic Concept

Dynamic flow scheduling based on real-time data movement prediction

- Real-time data flow prediction
- Intelligent flow and task scheduling
- Efficient and optimal routing policy management

![Diagram showing comparison between Hadoop (Original) and FlowComb](image)

- Value Differentiation

<table>
<thead>
<tr>
<th>Hadoop (Original)</th>
<th>FlowComb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial flow scheduling: routing reassignment</td>
<td>Manage data transfer</td>
</tr>
<tr>
<td>Transfer data at the same time</td>
<td></td>
</tr>
<tr>
<td>Link capacity</td>
<td>Link capacity</td>
</tr>
<tr>
<td>Time</td>
<td>Time</td>
</tr>
</tbody>
</table>

- Temporal task scheduling: flow prioritization and pacing

- 36% faster than Hadoop without FlowComb
  - (and 28% faster than Hadoop with ECMP)
Technology Collaboration: “SDN” x “analytics”

Prediction capability by real time analytics is the key
NEC’s Multiple Collaboration in SDN

NEC participated in the Clean Slate Program of Stanford University from its foundation, and is currently working with:

- **R&D:** ONRC (Stanford & UCB), Geni
- **Standardization:** ONF, ETSI
- **OSS:** ON.LAB (ONRC), OpenDaylight

![Diagram showing NEC's collaboration in SDN]

- **2008:** Participated in Clean Slate Program of Stanford University
- **2009:** Formulated and standardized OpenFlow specifications
- **2010:** OpenFlow R&D
- **2011:** World’s first OpenFlow products
- **2012:** Contribute Open Flow Switches to GENI
- **2013:** GENI Project

**SDN R&D**
- Open Networking Research Center
- Open Networking Foundation

**OSS activities for SDN software**
- OpenDaylight
- NFV ISG

**SDN standardization activities by telecom carriers**
SDN Contributing to Enhancement of Social Infrastructure

- Suppress failure occurrence
- Visualize the entire ICT system
- Optimize ICT resource balance
- Improve efficiency of infrastructure equipment
- Improve security

Advancement of ICT

Enhancement of social systems
Security
Security: Research Direction

Challenging increasingly complex and diverse threats with a broad range of technical expertise; system security, encryption, large-scale system analysis and risk analysis.

- **System security**: Flexible and supports different work styles. SDN Access Control — World’s 1st.
- **Database operations without decryption**: Secure computing — No.1.
- **Privacy protection**: Large-scale, fast. Personal data anonymization — No.1.
- **Copyright protection**: Editing-resistant illegal image copy discovery. Video signature — No.1.
- **Compliance**: 24000x faster than previous technologies. Business document analysis — No.1.

Minimize risk of targeted attack.

Minimize operations risks.
Important and new aspect in NEC’s research for making breakthrough technologies towards social value creation

Particularly, data analytics becoming the innovator of many other techs
Summary

Transformation of NEC’s research towards social value creation by ICT

New journey of discovering customer values in the emerging market
• Focus on 7 technology areas (Data analytics with leading focus)
• Create No.1/Only-1 core techs (unchanged)

Collaborative Innovation is of ever-increasing importance
• Collaboration with customers
  for finding out new direction of innovation
• Collaboration with academia, government, partners
  for open innovation, test bed & infrastructure for trails
• Collaboration between technologies
  for new breakthrough, for new infrastructure paradigm

Management encouraging

• Establishing competitive technical expertise (unchanged)
• Willingness to making collaborations / synergies even more than in the past
• Enhancing individual’s sensitivity to broader range of techs & innovations