IoT or CPS
Leveraging Internet for Smarter Grid

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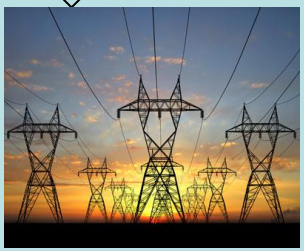
Current Grid

Coal

Nuclear

Gas

Transmission & Distribution



Residential

Industrial

Commercial

Smart Grid

Wind

Coal

Nuclear

Gas

Solar

Transmission & Distribution

Resident

Automobile

ndustria

Trains

ommercial

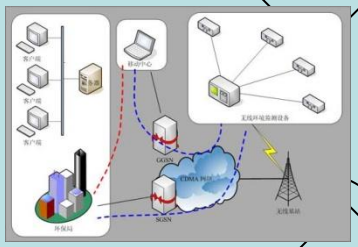
(Future) Internet

Datacenters

Datacenters

Datacenters

Transmission
& Delivery



Enterprises

MIDs

SOHO

Other Infrastructures

- High speed rail/trains
- Highways
- Airlines
- Petroleum/Gas pipelines
- Water supplies

Discrete

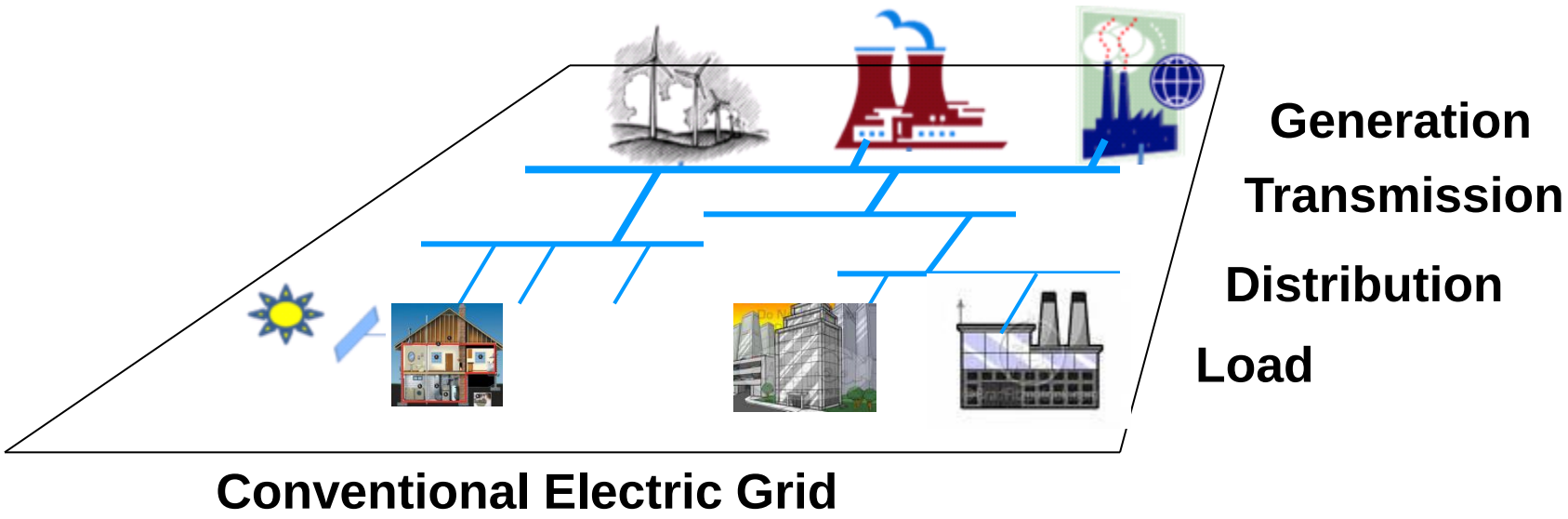
Continuous

- Transfer between stations/ports, etc.
- Bandwidth and latency limitations

IoT & CPS

- **Internet of Things**
  - **It was mostly computing and communication**
  - **+Sensors and sensor network**
  - **+Actuators and control system**
- **Cyber Physical System**
  - **Tight conjoining of and coordination between computational and physical resources**
  - **Pervasive/Ubiquitous/Symbiotic Computing**
  - **IoT=CPNet : IoT is to implement CPS in a wide-area networking environment**

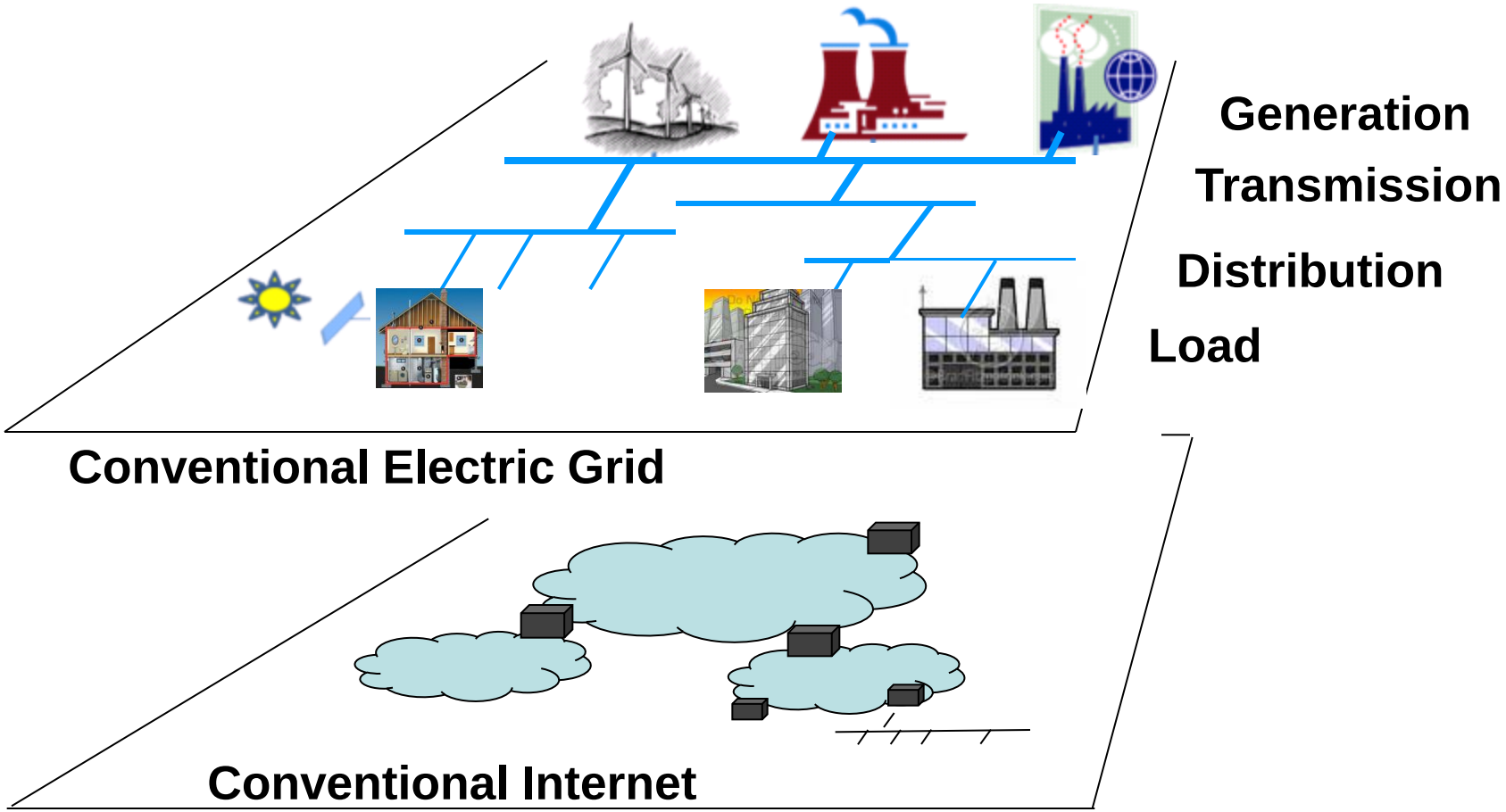
Grid Exists



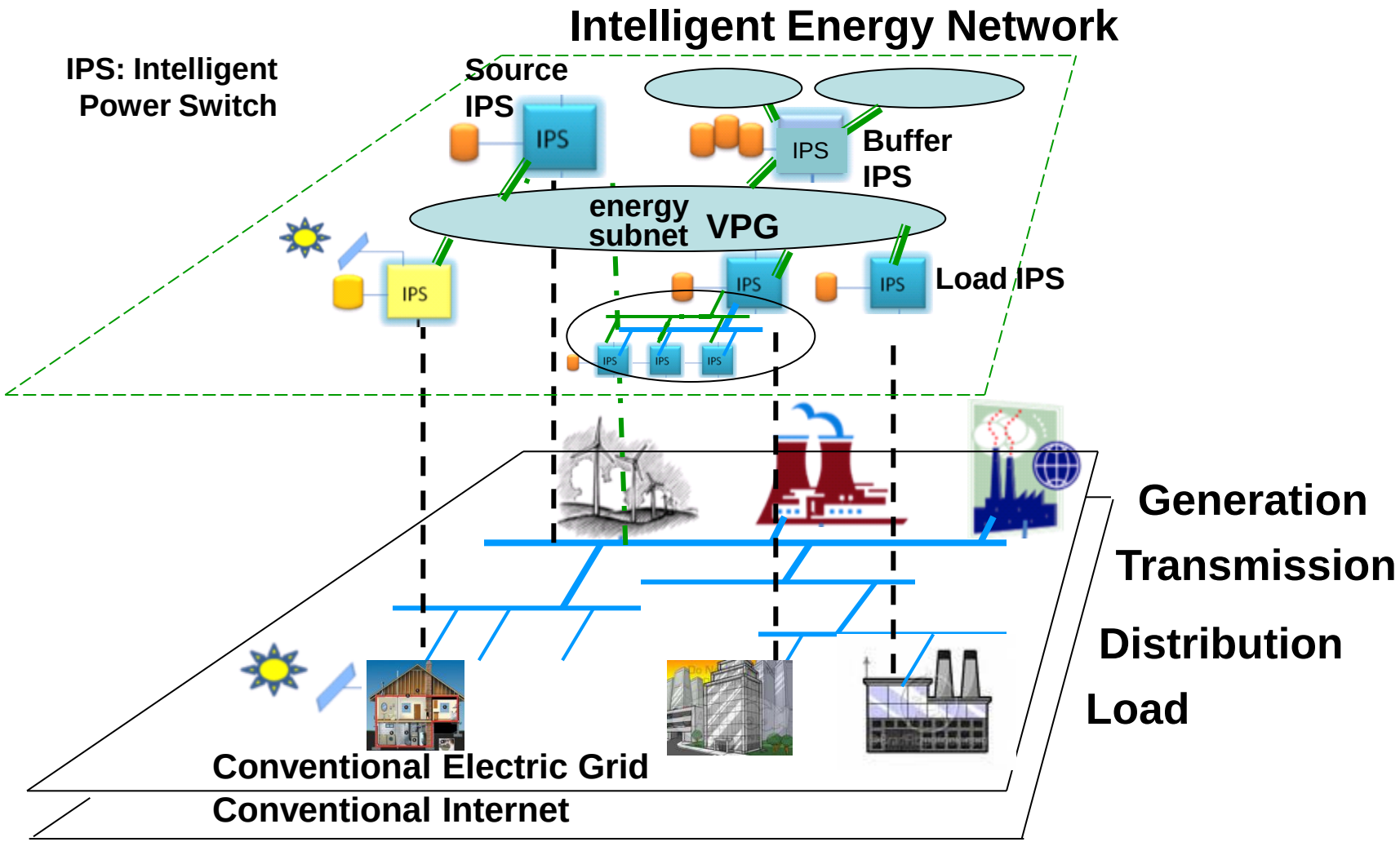
Conventional Electric Grid

Curtsey: A Network Architecture for Localized Electrical Energy Reduction, Generation and Sharing
David Culler

Internet Exists



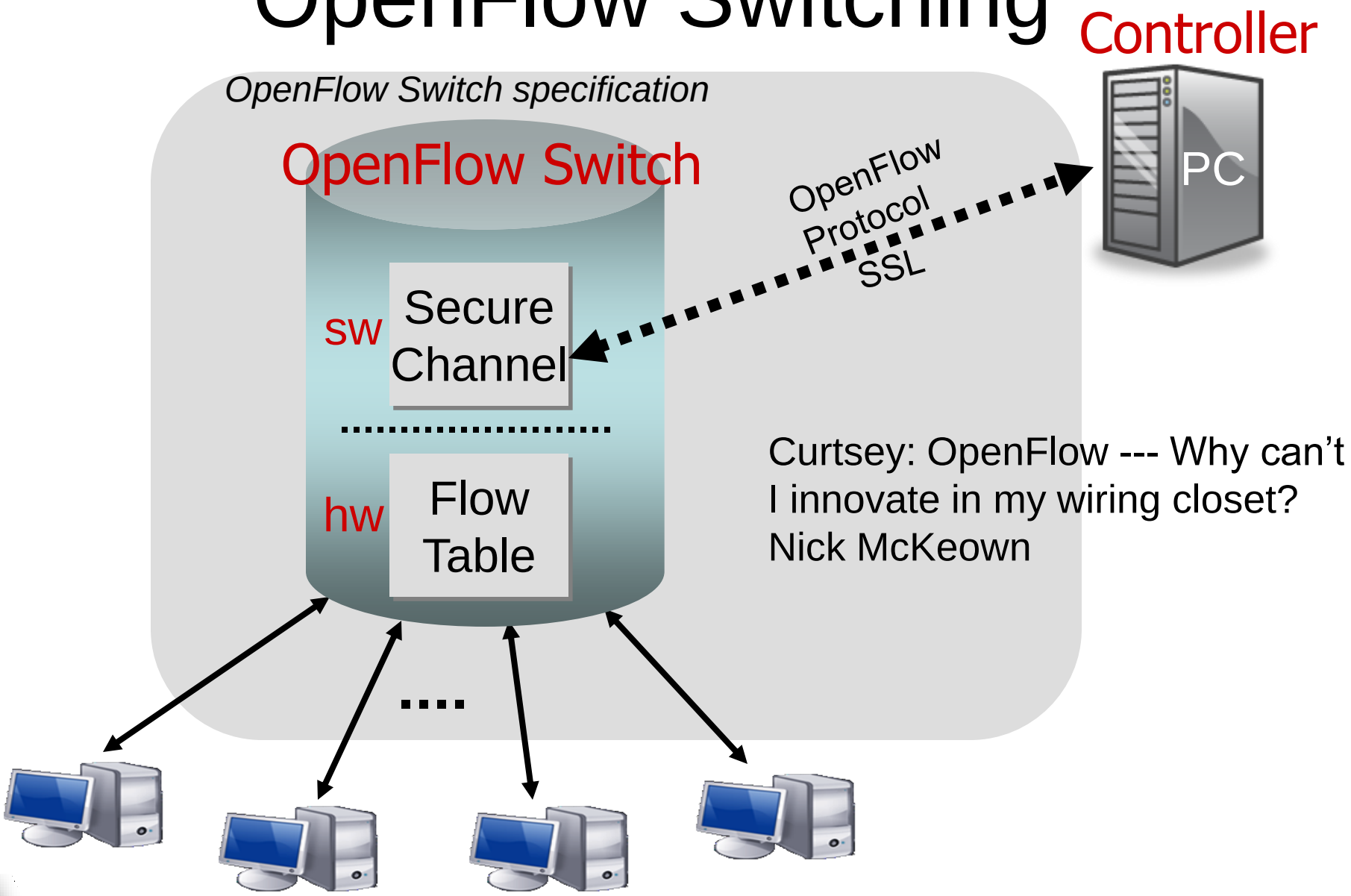
Intelligent Energy Network as Overlay on Both



Internet of Infrastructure

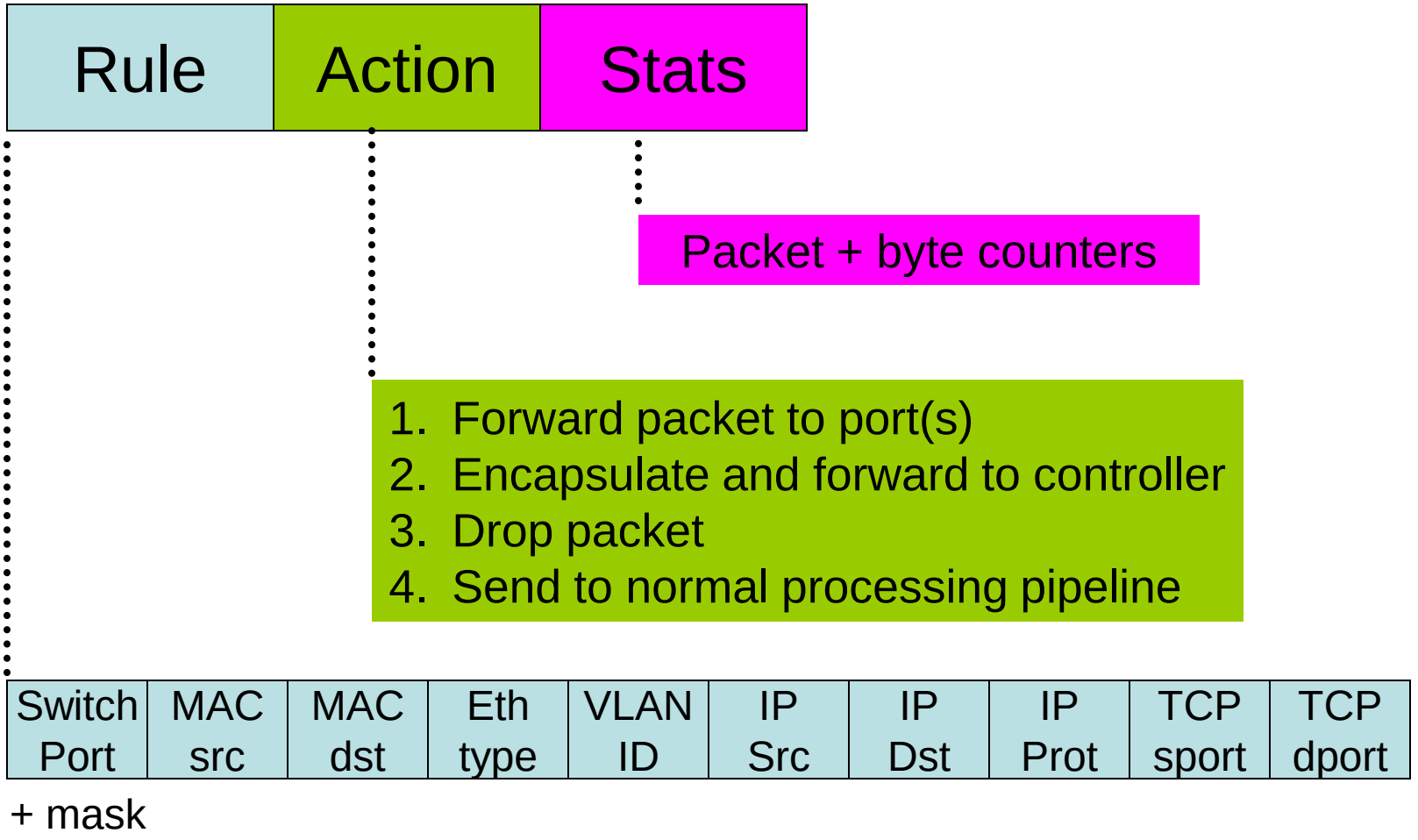
- Infrastructure needs Internet
  - Best available “nerve” system for infrastructure
  - Data/knowledge and processing power
  - Most advanced human interface
- Internet evolves for infrastructure
  - More (centralized) controllability
  - Better real-time capability
  - Higher reliability
  - Advanced security

OpenFlow Switching



Flow Table Entry

"Type 0" OpenFlow Switch



OpenFlow Advantage

- **Separate intelligence from datapath**
  - **Centralizes data collection and fusion**
  - **Allows in depth analysis and granular control**
- **Flexible flow path control**
  - **Enables multipath for latency reduction, load balancing, redundancy, and confidentiality**
  - **Opens up waypoints for middleware, such as access/admission control and intrusion management, as well as middleboxes**
  - **and a lot more possibilities to be developed**

Smart Resource Management

- Global resource optimization
  - Avoid local-optimal solution
  - Centralized management plane
- High-level configuration
  - Avoid on-site configuration effort
  - Automatic low-level control policy deployment
- Possible Approaches
  - Build secure management plane
  - Design reliable discovery mechanism
  - [OpenFlow, CCR'08]

Scalable Computing Capacity

- Computation Architecture
  - Smart decision-making for millions of nodes
  - Scaling up/down and in/out
- Content Organization
  - Massive data generated by nodes
  - Mixed critical and non-critical information
- Possible Approaches
  - Using datacenters for computation [NOX to DC, Hotnet'09]
  - Using hierarchical CACHE and HASH for storage [Onix, OSDI'10]

Fine-grain Control

- **Controllability**
  - **Reliable communication**
  - **Resource exposure**
- **Fine-grain**
  - **Different level of policy enforcing**
  - **Support extensible protocol processing**
- **Possible Approaches**
  - **Support standard management protocol [OpenFlow 2.0]**
  - **Using both proactive and reactive policy enforcement [DIFANE, Sigcomm'10]**

Cost-effective Deployment

- Cost of control elements
  - Millions of nodes
  - Redundant deployment
- Cost of system configuration
  - Expense of field engineering
  - Difficulties in re-deployment
- Possible Approach
  - Using virtualized topology for flexible and extensible deployment [Open vSwitch, HotNet'09]
  - Using network-wide operating system for configuration [Nox, CCR'08]

Security and Reliability

- **Secured control plane**
  - **Sending correct policy**
  - **Receiving correct message**
- **Reliable data plane**
  - **Real-time and critical messages**
  - **Fault-tolerance**
- **Possible Approach**
  - **Out-of-band secure channel with policy check [FlowVisor, OSDI'10]**
  - **Fine-grain QoS support [OF QoS, WERN'10]**

Our Research I

- **Key algorithms for OpenFlow**
  - **Stateful Inspection**
    - **for 10~100 Gbps packet classification and session processing**
    - **on commodity NP and FPGA devices**
    - **in *Infocom'09* and *FPT'10***
  - **Deep inspection**
    - **for 10 Gbps flow inspection**
    - **on of-the-shelf FPGA**
    - **in *Globecom'10* and *Infocom'11***

Our Research II

- OpenFlow-based Service-aware Network
  - Service-aware virtual topology
    - Virtual topology for different service networks
    - Based on switch device virtualization
  - Distributed service-aware processing
    - Offload centralized control to distributed systems
    - Meeting critical performance requirements
    - Saving network bandwidth

Conclusion

- Infrastructure and Internet will evolve into each other and emerge as IoT, CPS, or whatever you call it.
- This requires Internet to gain better controllability, reliability, and security, especially for Smart Grid.
- OpenFlow and its like enable many possible approaches, and brings a lot of challenges and opportunities for networking research.

Many thanks to my colleagues and students, especially Yaxuan Qi

Questions?