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National University of Defense Technology

Boosting Artificial Intelligence in Software Defined Systems with Open Infrastructure

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- 'software defined' is being labeled in a growing number of systems.

terminal

network

cloud

software defined radio

software defined radar

software defined mobile network

software defined sensor network

software defined satellite network

software defined cloud computing

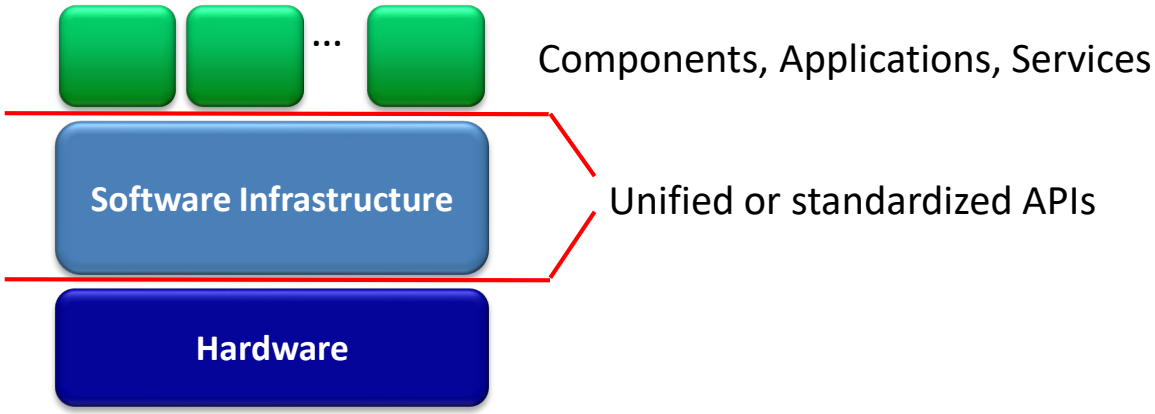
software defined data center

software defined storage

software defined visualization

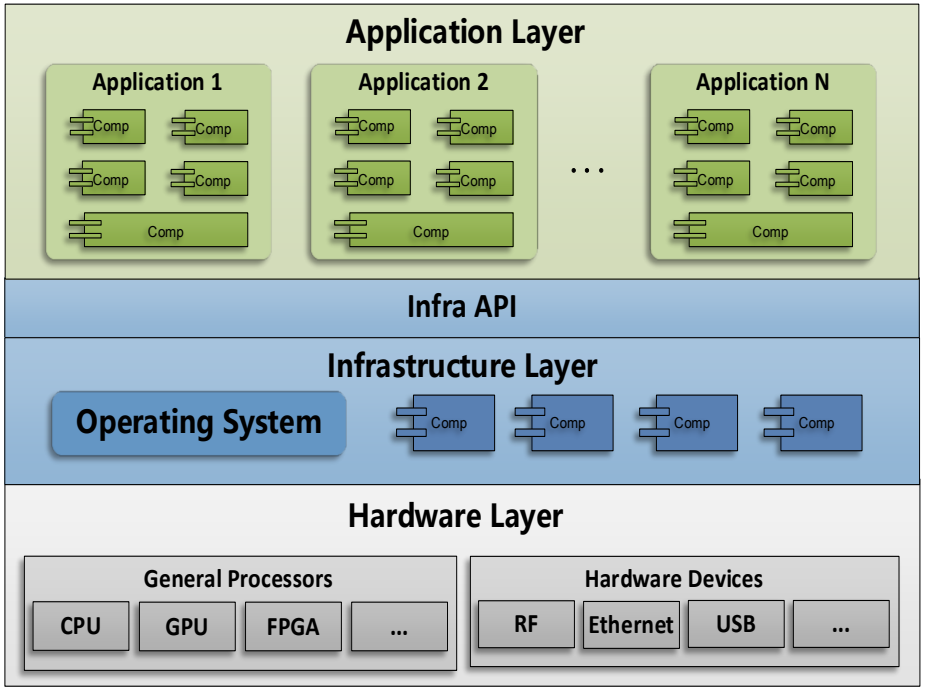
- Software infrastructure plays an essential role.

Type	Commercial	Open Source	Open Standard
Terminal	Windows, iOS	Linux, Android, ROS	SCA, STRS
Network	Cisco ACI, VMware NSX	Beacon, Floodlight, OpenDaylight, ONOS	OpenFLow
Cloud	Microsoft Azure, Amazon Web Services (AWS), Alibaba Cloud	OpenStack, Kubernetes	



Software Defined System

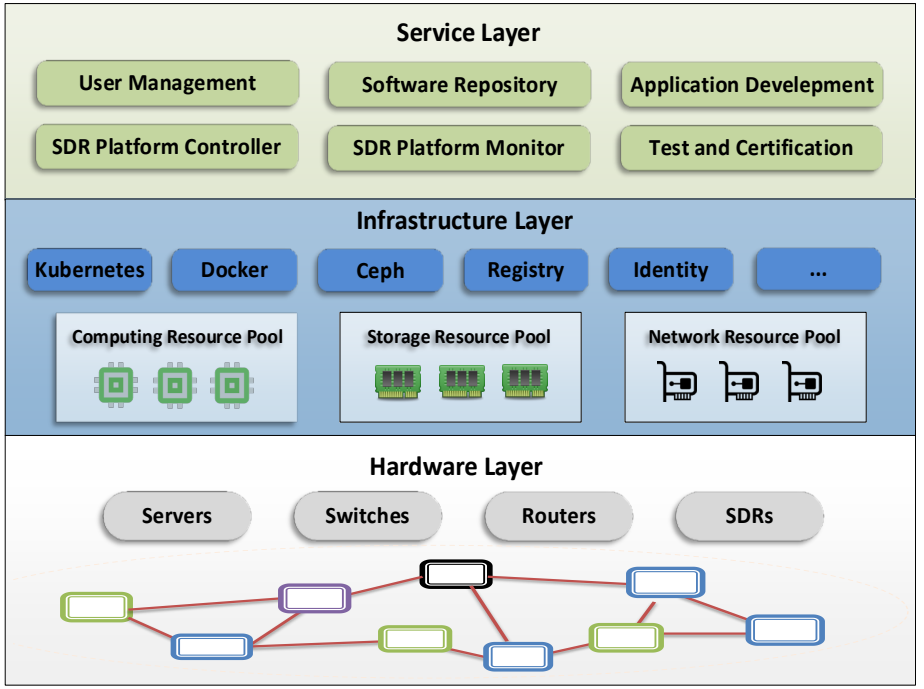
Terminal SDS



e.g. SCA

- Deployment, management, interconnection and intercommunication of software components

Cloud SDS



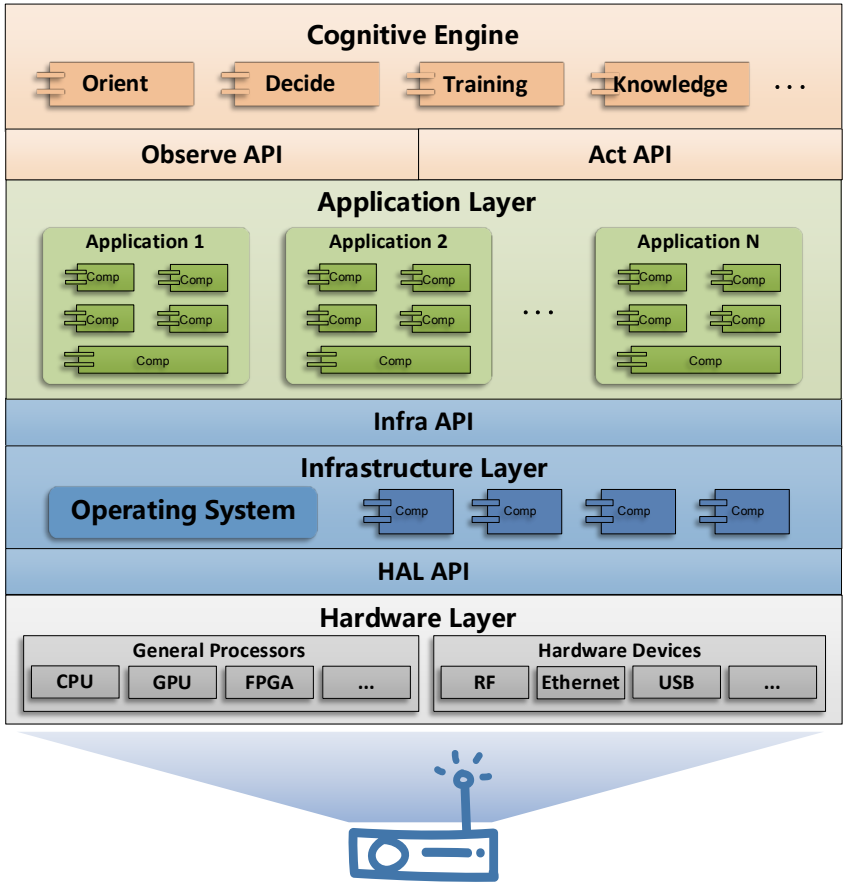
e.g. Kubernetes

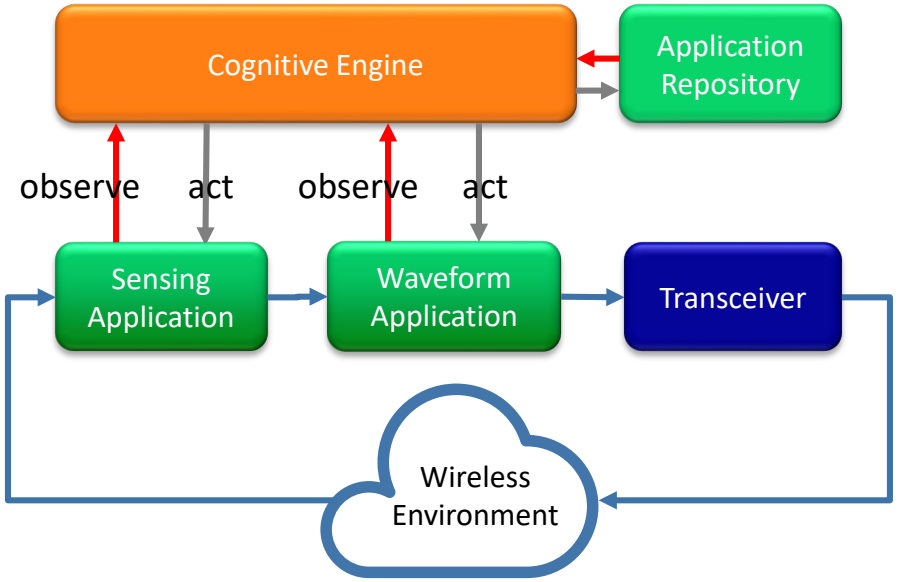
- Automate deployment, scaling, and management of containerized services

AI-able Terminal SDS

AI-able Terminal SDS

- Inspired by NASA Glenn cognitive communications systems project

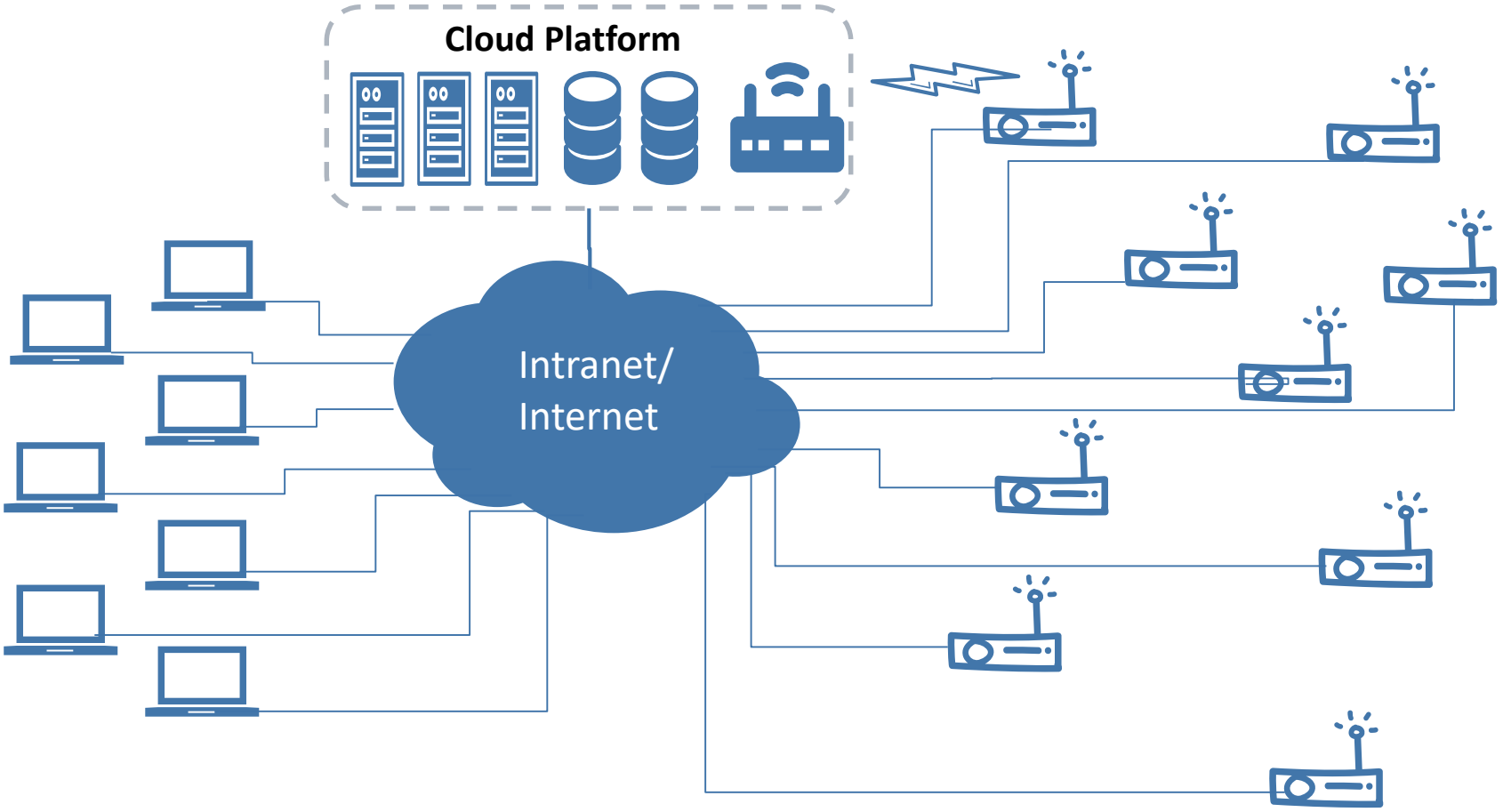




- Cognitive Engine: OODA Loop & Training
- Possible Hardware: CPU, GPU, AI Chips
- Observe:
  - query data from applications
  - spectrum data, parameters, etc.
- Act:
  - configure parameters into applications
  - Install/uninstall/start/stop/switch applications

How to boost AI in SDSs with open infrastructure?

SDSDevOps Environment



Open AI-able Cloud Infrastructure

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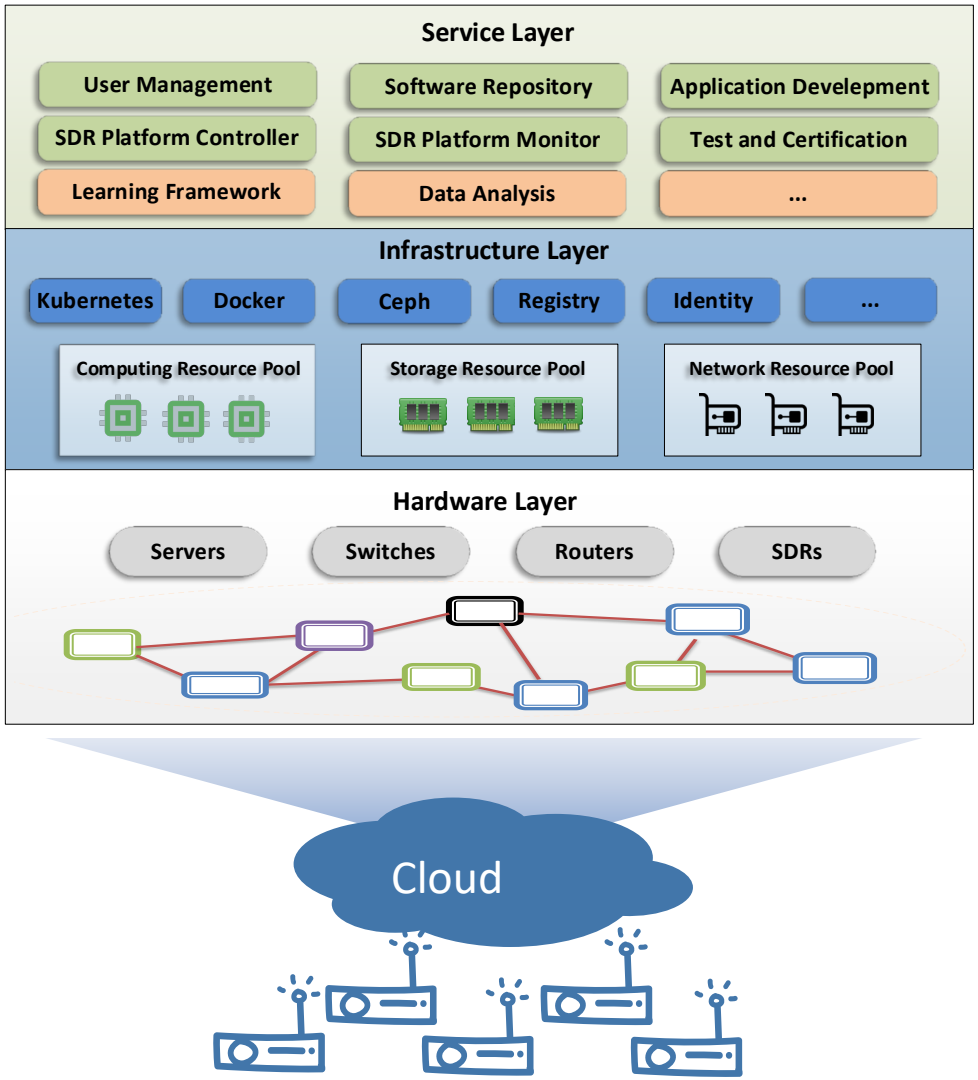


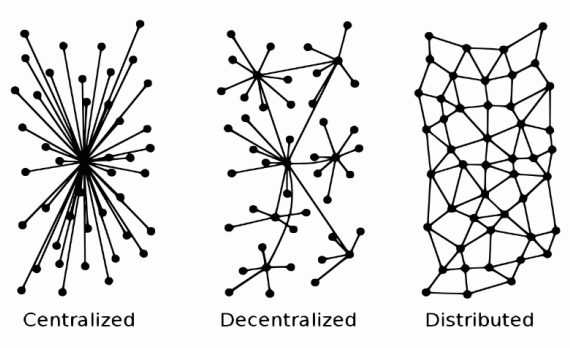
Basic Services

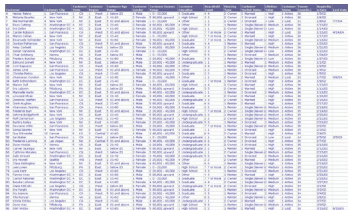
- User Management
- Software Repository
- Application Development
- SDR Platform Controller
- SDR Platform Monitor
- Test and Certification

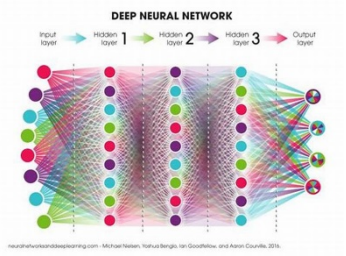
AI as a Service (AIaaS)

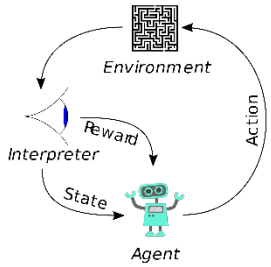
- Learning Framework:
  - TensorFlow,
  - Caffe,
  - PyTorch
  - …
- Data Analysis:
  - Pandas,
  - Statsmodels
  - scikit-learn
  - …

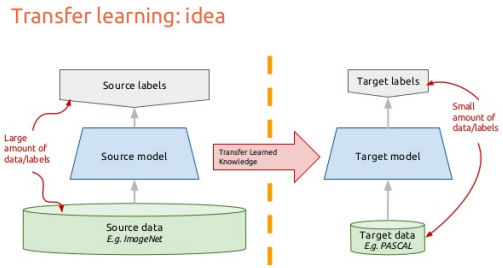
Open AI-able Cloud Infrastructure











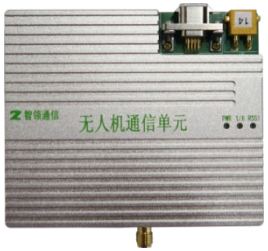
Optimize cognitive engines in SDSs

- Create training scenarios
  - Centralized networks
  - Decentralized networks
  - Distributed networks
  - Wired/wireless backhaul
- Build dataset
  - Geography data
  - Spectrum data
  - Channel data
- Train parameters
  - Neural network
  - …
- Train policies
  - Support Vector Machine
  - Reinforcement Learning
  - …
- Knowledge database
  - Transfer learning

Deployment on NUDT Campus

Indoor SDRs

Outdoor SDRs

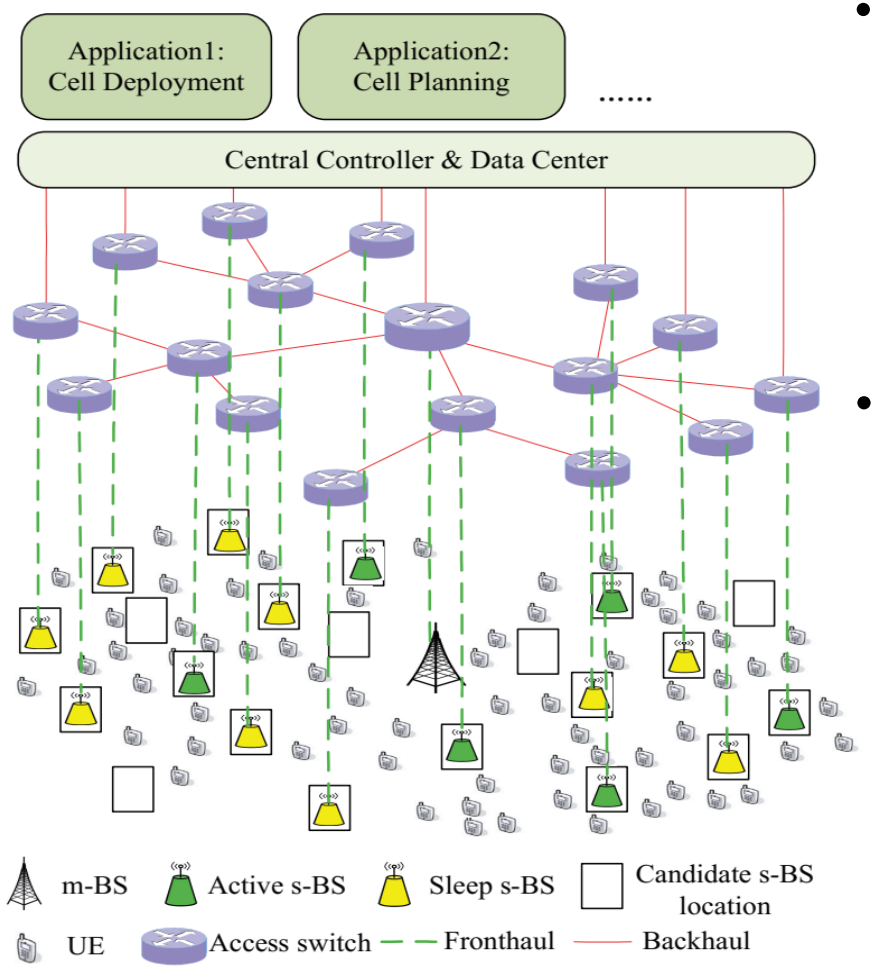


Cloud Servers

- 60 SDRs are deployed initially
  - 24 SDRs in the laboratory
  - 36 SDRs outside in the campus
- Cloud servers are deployed in the laboratory
  - Intranet deployment only currently
  - Internet deployment is on the way

Example Application (1)

e.g. Cell Deployment & Planning

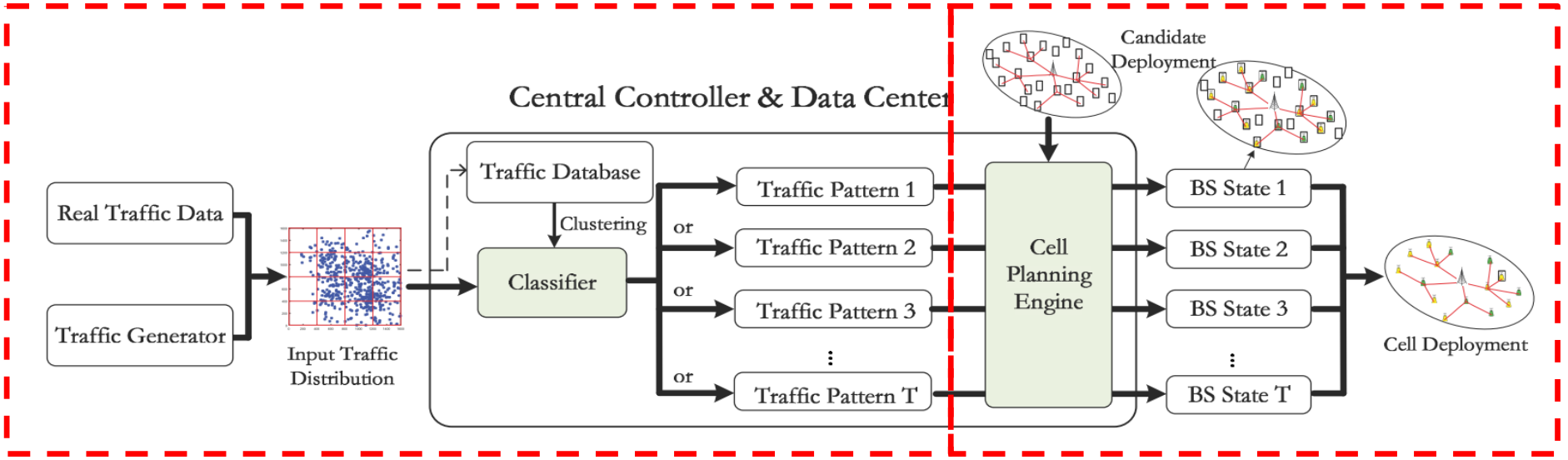


- **Assumptions**
  - Spatial traffic (user distribution) varies from time to time in a region following some traffic patterns.
  - Centralized controller & wired backhaul
- **Problems**
  - How to deploy minimal number of small cell base stations to meet users' spatial traffic requirements?
  - How to control the ON/OFF status of the small cell base stations to maximize energy efficiency?

L. Zhou, Z. Sheng, L. Wei, X. Hu, H. Zhao, J. Wei & V. C. Leung, "Green Cell Planning and Deployment for Small Cell Networks in Smart Cities". *Ad Hoc Networks*, vol. 43, pp. 30-42, June 2016.

Example Application (1)

e.g. Cell Deployment & Planning



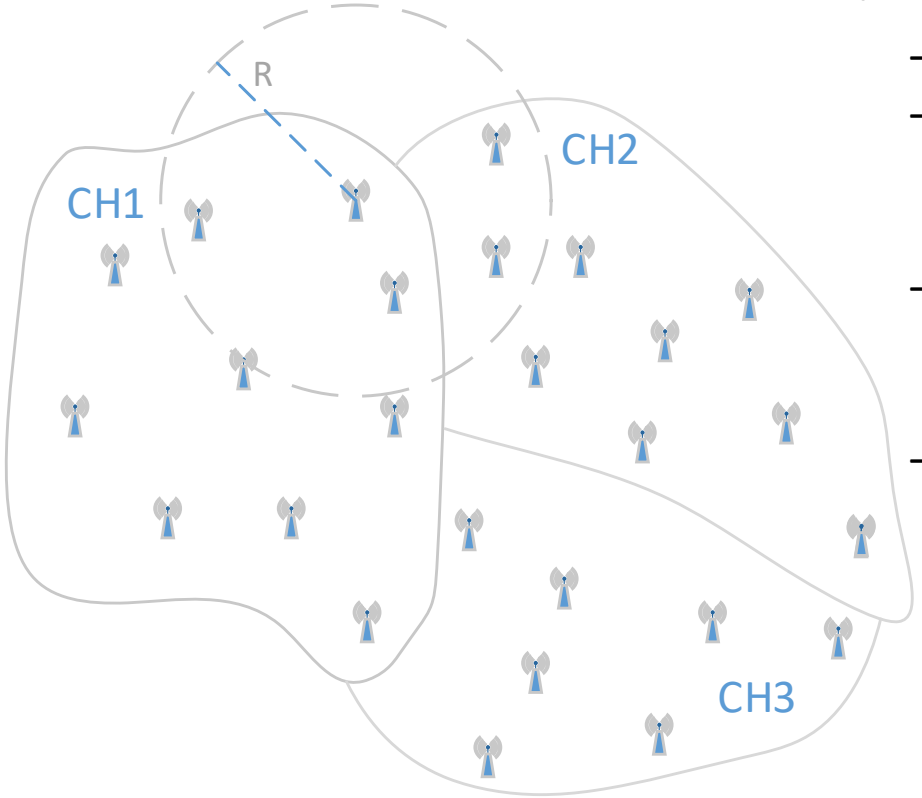
Traffic Clustering

Cell Deployment & Planning

- **Our approach**: Support Vector Machine (SVM) + Deep Neural Network

Example Application (2)

e.g. User Clustering



- **Assumptions**
  - Mobile ad hoc network
  - Users are divided into clusters distinguished by spectrum band (i.e., channels).
  - Too large cluster size would result in heavy intra-cluster communication collisions
  - Too small cluster size would result in large number of clusters, which leads to complex inter-cluster communication

- **Problem:** How to group users into clusters with optimal size?
- **Our approach**: Reinforcement Learning (POMDP) + Deep Neural Network

Summary and Future Work

- SDSDevOps is an environment that devotes to the development, operation, test and training of SDSs for students and researchers based on an open cloud infrastructure.
- Massive centralized/Decentralized/distributed, wired/wireless backhaul scenarios can be created.
- We plan to deploy and validate more applications that we used to study them by simulation on SDSDevOps.
  - Cooperative Spectrum Sensing
  - Cognitive MAC protocols
  - Resource Management
  - Mobility Management
  - …