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.

- 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 Defined System

National University of Defense Technology

• Software infrastructure plays an essential role.

<table>
<thead>
<tr>
<th>Type</th>
<th>Commercial</th>
<th>Open Source</th>
<th>Open Standard</th>
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</thead>
<tbody>
<tr>
<td>Terminal</td>
<td>Windows, iOS</td>
<td>Linux, Android, ROS</td>
<td>SCA, STRS</td>
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<tr>
<td>Network</td>
<td>Cisco ACI, VMware NSX</td>
<td>Beacon, Floodlight, OpenDaylight, ONOS</td>
<td>OpenFFlow</td>
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<tr>
<td>Cloud</td>
<td>Microsoft Azure, Amazon Web Services (AWS), Alibaba Cloud</td>
<td>OpenStack, Kubernetes</td>
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Components, Applications, Services

Unified or standardized APIs
Terminal SDS

Cloud SDS

e.g. SCA
- Deployment, management, interconnection and intercommunication of software components

e.g. Kubernetes
- Automate deployment, scaling, and management of containerized services
AI-able Terminal SDS

- Inspired by NASA Glenn cognitive communications systems project

<table>
<thead>
<tr>
<th>Cognitive Engine</th>
<th>Observe API</th>
<th>Act API</th>
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<tr>
<td>Orient</td>
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<td>Decide</td>
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<td>Training</td>
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<td>Knowledge</td>
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Application Layer

- Application 1
- Application 2
- Application N

Infra API

Infrastructure Layer

- Operating System

HAL API

Hardware Layer

- General Processors: CPU, GPU, FPGA, ...
- Hardware Devices: RF, Ethernet, USB, ...

How to boost AI in SDSs with open infrastructure?

- 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
Open AI-able Cloud Infrastructure

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
  - ...
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
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?

Example Application (1)

**e.g. Cell Deployment & Planning**

- **Our approach**: Support Vector Machine (SVM) + Deep Neural Network
**e.g. User Clustering**

- **Problem**: How to group users into clusters with optimal size?
- **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

- **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
  – ...