Wireless Software Defined Networking
Challenges and Opportunities

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Interesting facts

* Wireless Spectrum overcrowded but...
  * Only 2% of wireless spectrum between 30 Mhz and 3Ghz effectively used (measured in 2009 in dense urban area near Washington DC, USA)

* In UK more people connected to broadband than Water and Average utilization of internet link is....<1% but...

* Electronics and Software industries spend billion of dollars for verification and what about telecom?

* Surrounded by huge number of wireless AP and cellular BS from different operators and still not enough big MOBILE data rates
Motivations

- Evolution of underlying core protocols (TCP, IP) and Algorithms (congestion, ...) limited
  - Gradual deployment
  - Test on real testbeds not simulation
  - This is critical to avoid network ossification
- Performance
  - QoS
  - Seamless Handover
- Verification
  - “Black art”, no formal method upstream
Software Defined Network

* In 2007 seminal research papers propose decoupling forwarding plane (physical infrastructure) and control plane
* In the past (present) ...
* Routers no longer decide but only classify entering flow
* Action decided by a remote central entity: "controller"
* Flow: set of packets with same characteristics (among 12-tuple header’s field)
* Communication between devices and controller via OpenFlow protocol
* Define and Upload rule/action pairs into interconnection equipment
* Provides execution environment for programmatic control of the network → **Network Operating System (NOS)**
* Open source controller: NOX in C++, POX in Python
* Devices (switches, routers,..) send their state (no of packets of given flow that entered etc..) to controller
* Update policies dynamically based on this information
Opportunities
Network Planning

- Goal: allocate channels so that neighboring APs use different channels
Dynamic change to the best channel

- Close APs should use different channels so that they don't interfere
  - Planning, see above
  - Close access points often belong to different operators anyway...

- An AP could sense the surrounding channels occupancy and take a greedy local decision
  - Switch to the less busy channel

- Issue #1: clients have to switch too
  - It could break network connections => don’t do this often

- Issue #2: what if other APs apply the same policy?
  - May be useless, or cause oscillations
How can network virtualization help?

• A good percentage of Wi-Fi access points are set-top-boxes
  • Owned by the ISP

• In a single operator scenario:
  • All access points can report measurements to an area controller (building, ...)
    - e.g. use IEEE 802.11v extension
  • Can also report usage statistics (users signal attenuation distribution, ...)
  • The controller runs a planning algorithm (under constraint)
  • The controller uploads a policy (channel, TX power, ...) to the access points

• In a multi-operator scenario
  • Same strategy, except that controllers have to communicate together

• Bonus:
  • Inter-operator QoS management becomes possible
Wireless SDN proof of concept: redundant transmission

- WLAN has a limited throughput and are sensitive to congestion:
  - Global performance is disappointing when the user is used to wired LAN
  - Multimedia content is tailored for Ethernet LANs

- Solution at the signal level: MIMO
- Solution at the packet level: duplicate the packet and send it through different paths
  - Requires a multi-interface terminal
  - Can work across technologies (e.g. Wi-Fi and LTE smartphone)

- Scenario implemented as an OpenRoads demo
Cross-layer redundant transmission for multimedia applications

- Multimedia flows are sometimes composed of different types of frames
  - Example: MPEG flow
  - I-Frames: full images
  - P-Frames: “predicted” images (contains only differences from the previous image)
  - B-Frames: “bi-directionnal predicted” images (differences between the previous & the next images)

- Loss or delay does not have the same effect on all types of frames

- Where SDN can help
  - Transmit I-Frames on the best channel, P and B frames on the other
  - Adapt video quality to network conditions (filter detail frames, ...)

Full MPEG flow
Handover management

- Horizontal handover (from AP to AP)
  - Channel measurements ease mobility prediction
  - SDN enables dynamic redefinition of forwarding rules to duplicate traffic over two APs
    - Need mechanism to filter duplicate packets at the reception
- Vertical handover (between technologies)
  - Similar technique as horizontal handover when controllers collaborate
  - Mobility prediction requires the device to decide whether to switch
- Scenarios are already demonstrated by OpenRoads

Source: Blueprint for Introducing Innovation into Wireless Mobile Networks by K.K. Yap et al.
Energy efficiency in WLAN - Adaptive Link Rate

- Energy consumption varies with the load (with the same channel throughput)
  - Transmission: ~ linear
  - Reception: more efficient at higher throughputs
  - Seems in favor of traffic aggregation on the same Access Points

- Physical layer rate switch (ARF)
  - Modulation and range differ with the L2 throughput
  - Decreasing the physical rate and transmission power could help preserve energy
  - However, lower bitrates occupy the channel longer and require longer preambles
  - No thorough experimental study at this date
  - Changing the data rate of a single station affects the whole cell

- Power control...

Rerouting traffic to a limited subset of APs to switch off APs
- Tightly linked to power control / coverage problems

Interface proxying
- WLAN interfaces can be put asleep when no traffic from/to the terminal
- In-network rerouting of control traffic (ARP, ICMP, TCP keepalive, DHCP, ...)
- How to wake up the device when incoming traffic arrives?
Challenges in a wireless LAN
Slicing

- Create multiple virtual networks from a single physical network
- Slicing done by FlowVisor
  - Illusion: a controller manages a dedicated network
  - Long Term vision: decoupling between “physical infrastructure” and “service provider”
Slicing issues: Wireless Medium Sharing

* Numerous papers evaluate performance of WLAN-like protocols
  * Successive 802.11 versions, different scenarios, different tools (models, simulation, experiments, ...)
  * One common conclusion: Wi-Fi scales poorly when the load increases

* Not many independent channels
  * ➔ Not much latitude to create independent (i.e. non-interfering) slices
  * Share channels between user types (primary vs. secondary) and traffic classes

Multi-ISP scenario: risks and challenges

* Radio resources management works better if ISPs collaborate

* What happens when some access points don't collaborate?
  * Is there a way, with current Wi-Fi standards, to handle uncooperative and selfish players?

* How to make ISPs collaborate without risk?
  * Commercial risks (could bring knowledge of the exact number of subscribers, locations, etc. to competitors)
  * (Limited) Security risks: malicious attacker could send false information to trigger channel switches
Conclusions
Software defined networks are composed of
- Centralized controller(s)
- Interconnection devices: multiple fields-based matching (cross-layer)
- Measurement points that report to the controller(s)

They offer a framework for multiple in-network optimizations
- Coordinated channel allocation
- Channels aggregation to improve QoS
- Handovers between operators (packet networks roaming)
- Energy savings
- etc.

But require an efficient slicing (i.e. build independent networks)
- Not easy with a limited number of independent channels
Open Issues

- Find a generic and efficient solution for opportunistic slicing
  - Spectrum sensing, power control, spectrum management

- How to build distributed controllers?
  - Within a single control domain (synchronization, hierarchy, ...)
  - Across control domains (e.g. between ISPs, how to preserve privacy, security, ...)
  - What if controllers disagree?

- How to involve terminals?
  - Cooperative detection
  - Apply decisions of the controller(s)
* Academy
  * Stanford & Berkeley : ON.LAB
  * Princeton
  * Georgia Tech, Cornell, ...

* Industry
  * NEC : Openflow switches..
  * Google (Openflow deployed in its dedicated backbone)
  * Deutsche Telekom (with TU Berlin)
  * Nicira by VMware
  * ...

* Other
  * ONF
Horizon 2020 and SDN

ICT 14 – 2014: Advanced 5G Network Infrastructure for the Future Internet

Strand Radio network architecture and technologies

* Network architecture, protocols and radio technologies capable of at least a ten times increase in frequency reuse,... The work takes into account novel requirements from cloud networking, from a multiplicity/diversity of connected devices and services to be served and content delivery/cell broadcast/caching requirements.

Strand network management

* Combination of software defined network implementations with autonomic management of resources;
* Network security across multiple virtualised or SDN domains, with analysis of risks and vulnerabilities,...

Strand Network virtualisation and Software Networks

... Innovation actions

* At macro level, the target impact is
  i) to create an NFV/SDN industrial capability in Europe with European providers able to compete on a US dominated market by 2020;
  ii) to reach large scale operational deployment of NFV/SDN based networks in Europe by 2020.

ICT 7 – 2014: Advanced Cloud Infrastructures and Services
The End...

Thank you...
Merci...
Danke...