Wireless

Wi-Fi

Wi-Fi Radio Resource Management (RRM)/Self Organizing Networks (SON) Technical Report

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1 OBJECTIVE

The primary goal of Wi-Fi Radio Resource Management (RRM)/Self Organizing Networks (SON) is to provide efficient operator managed and vendor interoperable Wi-Fi radio performance in the presence of large and dynamically changing numbers of APs and heavy user traffic. This report describes a strategy of leveraging a Wi-Fi SON server in the cloud/network that updates AP RF configurations based upon changes in local user traffic or networks topologies to help improve throughput and the user experience.

The primary use case for RRM with SON is in MDUs where a significant portion of APs are managed by the MSO, although other use cases may apply.

The Wi-Fi SON server is capable of running RRM algorithms which gets the inputs in the form of read parameters from the network and which gives out write parameters as outputs into the network.

Additionally, a Wi-Fi SON server does the following:

- Optimizes network performance by modifying the RF parameters.
- Maintains a real time database of the RF parameters, which will be used as inputs to the SON algorithms.
- Manages coverage and interference including multi-band selection for better traffic load balancing.
- Leverages SON (Self Organizing Networks) concepts and [802.11k] protocol for better RRM in massive and congested network deployments.
- Addresses the dense indoor/residential deployment problems wherein low-cost Cable Wi-Fi deployments consist of non-intelligent standalone APs.

RRM/SON allows the operators to manage the radio environment among various vendor solutions, or even unify RRM approach among certain AP vendors.

2 SCOPE

The challenge to Wi-Fi operators to provide a satisfactory subscriber experience with the promised throughput rates is increasing, given the proliferation of Wi-Fi APs and devices with growing subscriber traffic demand. Operators are considering more effective radio resource techniques in order to help manage a satisfying user experience. RRM becomes very important, particularly in dense residential deployments where vendor interoperability is an issue.

This report addresses the advantages of using a centralized SON server in the operator network and the work that CableLabs has done in this domain to help improve RRM. In the process, this report also addresses the possible network architectures in the presence of a SON server and how [802.11k] can be part of an overall Wi-Fi radio resource management strategy.

3 INFORMATIVE REFERENCES

This technical report uses the following informative references. References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific. For a non-specific reference, the latest version applies.

[3GPP SON]	3GPP Self-Organizing Networks, http://www.3gpp.org/technologies/keywords-acronyms/105-son.
[802.11]	IEEE Std 802.11-2012, IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.
[802.11k]	IEEE Std 802.11k-2008. IEEE Standard for Information technology- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC)and Physical Layer (PHY) Specifications Amendment 1: Radio Resource Measurement of Wireless LANs.
[Voice over Wi-Fi	Wi-Fi CERTIFIED™ Voice-Enterprise: Voice quality and bandwidth management tools for the enterprise, http://www.wi-fi.org/discover-wi-fi/wi-fi-certified-voice-programs
[WBA Carrier Guidelines]	WBA Carrier Guidelines, http://www.wballiance.com/resource-center/wba-white-papers/
[WBA Carrier Wi-Fi]	Carrier Guidelines, http://www.wballiance.com/wba/wp-content/uploads/downloads/2014/03/WBA-Carrier-Wi-Fi-Guidelines-v1.0.pdf
[WiFi-GW]	Wi-Fi Requirements for Cable Modem Gateways, WR-SP-WiFi-GW, http://www.cablelabs.com/specs/specification-search/
[WiFi-ROAM]	Wi-Fi Roaming Architecture and Interfaces, WR-SP-WiFi-ROAM, Specification, http://www.cablelabs.com/wp-content/uploads/specdocs/
[WR-SP-WiFi-MGMT]	Wi-Fi Provisioning Framework Specification, WR-SP-WiFi-MGMT, http://www.cablelabs.com/specs/specification-search/

3.1 Reference Acquisition

- 3rd Generation Partnership Project, (3GPP), http://www.3gpp.org/
- Cable Television Laboratories, Inc., 858 Coal Creek Circle, Louisville, CO 80027; Phone +1-303-661-9100; Fax +1-303-661-9199; http://www.cablelabs.com
- Internet Engineering Task Force (IETF) Secretariat, 46000 Center Oak Plaza, Sterling, VA 20166, Phone +1-571-434-3500, Fax +1-571-434-3535, http://www.ietf.org
- Wi-Fi Alliance (WFA), http://www.wi-fi.org/
- Wireless Broadband Alliance (WBA), http://www.wballiance.com/

4 ABBREVIATIONS AND ACRONYMS

This document uses the following abbreviations:

ACS	Auto Configuration Server
AP	Access Point
BSSID	Basic Service Set Identifier
CM	Cable Modem
CMTS	Cable Modem Termination System
CWLAN	Carrier Wi-Fi LAN
DOCSIS®	Data-Over-Cable Service Interface Specifications
LTE	Long Term Evolution
MAC	Media Access Control
MCS	Modulation and Coding Scheme
MDU	Multi-Dwelling Unit
MIMO	Multiple-input multiple-output
NBI	North Bound Interface
NPD	National Product Development Research Group
POC	Proof Of Concept
RF	Radio Frequency
RRM	Radio Resource Management
SBI	South Bound Interface
SSID	Service Set Identifier
SON	Self Organizing Network
STA	Station
VoD	Video on Demand
WFA	Wi-Fi Alliance
Wi-Fi	Wireless Fidelity
Wi-Fi AP	Wi-Fi Fidelity Access Point
Wi-Fi GW	Wi-Fi Gateway
WLC	Wireless LAN Controller

5 MARKET DRIVERS FOR RRM/SON

With the advent of multiple mobile devices, every house has at least 5.7 devices according to a study by the NPD Group[1.] Wireless data usage is expanding at an exponential rate and will only continue to increase in years to come. Due to this, there is an onus on the operators to provide high throughput, low-latency services to their customers thereby supporting high bandwidth applications in home. A number of applications and services like Internet browsing, Video on Demand (VoD), interactive programming, 3D gaming, location based services etc. are being offered to the customers as a part of the cable services.

On the access side, networks are becoming more and more complex and with the advent of new technologies, traffic offload and inter-networking is becoming more and more common. It is therefore incumbent on the operators to not only manage their access networks successfully but to also provide the necessary bandwidth and speeds to support the above mentioned applications and services in home.

This calls for a significant improvement in the traditional radio network planning and network management for managing the growing traffic volumes and network complexities in a cost effective manner. Additionally, there is a need to manage certain functionalities of the network elements automatically.

[3GPP SON] defines SON as a technology to configure network elements, optimize performance and to provide self-healing capabilities incase of network interference or faulty network elements. SON is a well-established concept in the world of LTE.

Infonetics Research released excerpts from its 2013 SON and Optimization Strategies: Global Service Provider Survey[2], for which Infonetics interviewed wireless, incumbent, and competitive operators around the world about their network optimization strategies and self-organizing network (SON) deployment plans. 87% of the operators who responded to the survey have deployed SON in their networks. The proliferation of SON in LTE networks suggests that larger operator-managed Wi-Fi networks could also take advantage of self organizing techniques.

[1] The NPD Group, http://thenextweb.com/insider/2013/03/18/npd-us-homes-now-hold-over-500m-internet-connected-devices-with-apps-at-an-average-of-5-7-per-household/

[2] Weissberger, Alan, 2013: Infonetics: 87% of Mobile Operators have Deployed Self Organizing Networks, found at http://community.comsoc.org/blogs/alanweissberger/infonetics-87-mobile-operators-have-deployed-self-organizing-networks

6 CABLELABS' CONTRIBUTIONS TO RRM/SON

A number of cable MSOs is interested in Wi-Fi RRM/SON to optimize network performance in dense residential deployments.

CableLabs formed an RRM/SON vendor focus team consisting of both MSOs and vendors to help address the dense deployment problem. The focus team was instrumental in converging on and defining a set of read, write parameters, which govern the RRM/SON interface from the SON server. CableLabs has also defined RRM/SON use cases, based on which the SON algorithms could be triggered in the SON server. Section 7 explains the architectures in detail.

Additionally, CableLabs was involved in leading this effort with a tier one Asian mobile operator in WBA.

6.1 Concept of Operations for RRM SON

The primary goal of Wi-Fi SON is to ensure the best network performance to the user by addressing first order changes in the network environment. Another primary goal is for SON to be automated so that operational burden is reduced. More specifically, a few essential radio interface management parameters are updated when the SON server detects:

- Changes in network topology, for example the addition or removal of an operator AP
- Changes in the local environment, for example when operator APs see other Wi-Fi networks emerge or disappear
- Changes in interference conditions
- Changes in traffic patterns that effect the status of congestion hotspots

With these changes in the environment are detected, the SON server can update the RF management parameters on the APs under its control in order to improve throughput to subscriber devices. For example, when operator managed APs are added the transmit power of certain other operator APs may be lowered to reduce interference. As another example, the carrier sense threshold of certain APs may be adjusted based on changes in interference conditions. The SON server does not attempt to response to localized actions by clients of APs that need to be dealt with in msecs by a local AP. Rather, the SON server takes a network wide view of first order conditions that can be responded to periodically to improve overall network performance in the longer term.

Typical operational use of the SON server would be for the SON server to poll relevant information from the network APs over a time span of several days or a week. When the total set of information is available from a collation of APs for a given area of interest, the SON server may update the RF parameters for specific APs. Therefore, any given AP may need to provide information to the SON server only once a week, and see configuration updates only occasionally. This approach helps reduce the overhead of Wi-Fi SON functions. It also reduces the operational staff hours required to manage the network since the SON server management functions of the APs are automated. Studies, prototype tests, and a 30,000 AP operational Wi-Fi SON managed network in Asia all show substantial increases in throughput (50% or more) using this SON concept of operations.

An essential component for SON operations is support for standardized and open interfaces between the SON server the APs. The algorithms used for the SON server to adjust the AP RF parameters, however, are intended to remain vendor or operator proprietary in order to encourage continued innovation.

6.2 Status of the specifications

One of the major goals and achievements of the RRM/SON effort was to update the industry specifications. RRM/SON is now a part of the WBA's Carrier Wi-Fi Guidelines and the CableLabs Wi-Fi Gateway Management specification.

6.2.1 WBA's Carrier Wi-Fi Guidelines

As per [WBA Carrier Guidelines] Carrier Wi-Fi LAN (CWLAN) is defined as the carrier operated public Wi-Fi network, which is different from the consumer and enterprise networks meaning operators will have the means to manage radio resources, including the ability to, but not limited to, manage the following list of parameters below. The CWLAN will provide means to manage these parameters through standardized interfaces.

- Transmit power
- MCS rates
- MIMO and MU-MIMO configurations
- Beam forming configurations
- Channel bandwidth
- Maximum throughput per device
- Carrier sense thresholds
- Multi Band configuration and steering of devices, which can include dynamic traffic load sharing across bands
- Subscriber and service-driven dynamic load balancing among APs, bands and channels
- Channel assignments
- Interference avoidance and mitigation for higher density deployments

The CWLAN will support the operator's ability to collect and monitor the KPIs listed below. (Note that KPI value ranges may need to be targeted to certain services):

- Received signal strength from devices
- Noise and interference levels
- Packet error rates and packet loss rates
- Throughput of uplink and downlink per device
- Device location
- Load threshold indicators
- Channel utilization
- Band utilization
- Rogue AP detection
- Neighbor AP detection
- Delays, latencies and jitter for traffic uplink and downlink

6.2.2 CableLabs' Wi-Fi GW MGMT specification

The [WR-SP-WiFi-MGMT] specification gives the management requirements for the Wi-Fi air interface and roaming as defined in the [WiFi-GW] and [WiFi-ROAM] specifications respectively. This specification states that the Wi-Fi GW should be able to report RRM related parameters (called read parameters) to the Wi-Fi SON controller and should allow RRM related parameters to be set by the SON controller (called write parameters). These parameters are defined in Section 8 of this document.

7 RRM/SON ARCHITECTURE AND INTERFACES

- The Wi-Fi SON server can be cloud/network based which will interface with different network elements depending on MSO requirements and architecture. Figure 1 below lists the possible interfaces from a Wi-Fi SON server.
- *Interface 1*: Wi-Fi SON server→ACS→WLC→APs
  - This option serves well for vendors with Wireless LAN Controllers and thin APs
- *Interface 2*: Wi-Fi SON server→WLC→APs
  - This option is for vendors whose WLCs interface directly with the SON server without an ACS.
- *Interface 3*: Wi-Fi SON server→ACS→APs
  - This option is for the standalone AP vendors.
- *Interface 4*: Wi-Fi SON server→ APs
  - This option is for standalone AP vendors, which can directly interface with the SON server.

For a Wi-Fi RRM/SON server to be able to interoperate with various vendor solutions, both the Wi-Fi GW and WLC must support TR-069/SNMP at its North Bound Interface (NBI).

The interface between the SON server and an ACS can be a web services based one. A number of MSOs are looking at web services framework for this interface.

The SON server should be able to support the standardized [802.11] protocols like 802.11k, 802.11v and 802.11r. All these protocols are currently a part of the WFA (WiFi Alliance) Voice Enterprise certification program. The interface between the WLC and the thin APs is vendor proprietary. We recommend using [802.11k] protocol for the interface between the AP and the STAs.

802.11k air interface features help devices make improved AP selection based on current radio and traffic conditions. With 802.11k, the WFA aims to support device transitions across APs within 50msec in the face of heavy traffic. 802.11k also provides a standardized MIB that reports key parameters to the network.

Noise levels, received signal strength, the number clients being served, and other RF environment characteristics are available to the operator to help them understand and manage their Wi-Fi radio access network. But 802.11k does not offer a standardized MIB that supports the adjustment of AP settings for the operator to manage the air interface. Furthermore, 802.11k does not provide a means to steer clients through multiple bands or channels, which is an important element of radio resource management.

Additional capabilities to control the APs are needed for the operator to adjust their RF environment based upon information available from 802.11k. In summary, 802.11k helps devices make better selection of APs and SSIDs based on the RF environment. It allows APs to report critical radio environment information to the Wi-Fi network operator. But 802.11k does not specify a standard AP configuration interface that can be used by operators cause APs to direct devices to bands or channels, or to manage AP RF settings, although these can be part of other standardized IEEE MIBs. Therefore, 802.11k can play an important part in reporting the RF environment to operators when combined with controller and AP management interface capabilities.

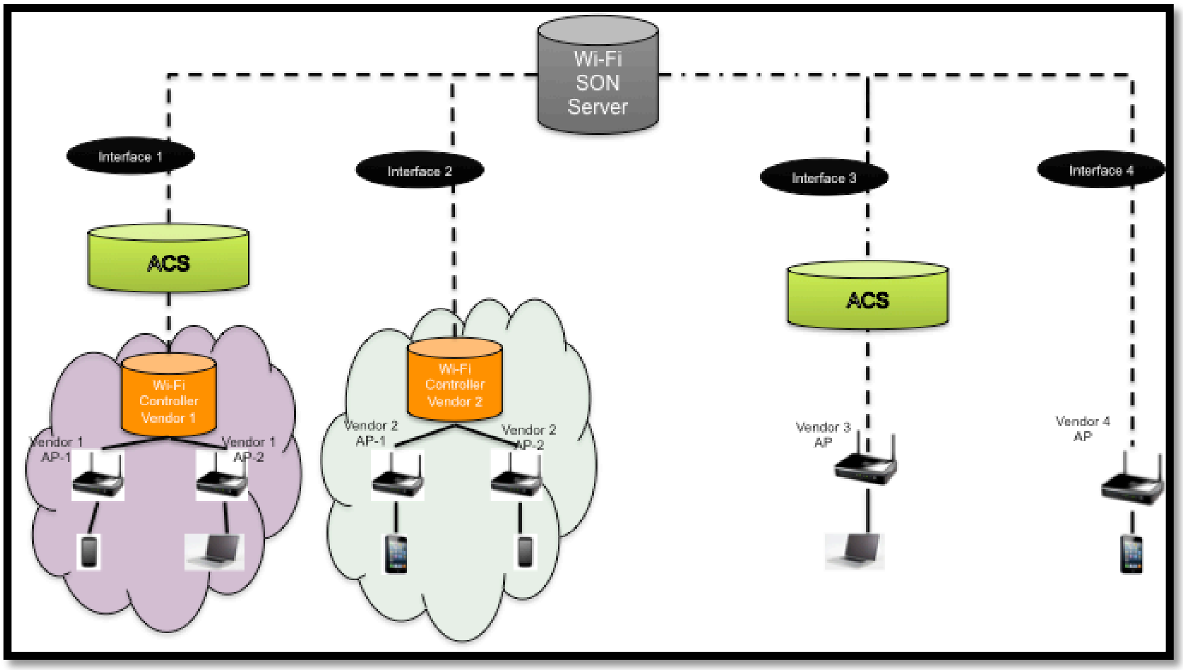

Figure 1 - RRM/SON Architecture Diagram

Each SON server will run its own proprietary SON algorithms, which are governed by the RRM/SON use cases. Load balancing, Neighbor list generation and optimization, QoS related parameter optimization, Coverage hole detection etc. are a few use cases. It is up to the discretion of an operator to define RRM/SON use cases. Each SON algorithm will take in a set of inputs (read parameters) and will produce a set of outputs (write parameters) into the network.

These read and write parameters are a part of the UML diagram as well which can be seen in [WR-SP-WiFi-MGMT].

8 RECOMMENDED FUTURE WORK

CableLabs is working with vendors to implement the RRM/SON parameters and support the various interfaces that are shown in this document. Once there is considerable vendor participation, CableLabs can host a Proof of Concept (PoC) interop for RRM/SON. Per MSO requests, CableLabs can address standardizing the RRM/SON interfaces since MSOs have different architectures for different kind of services. Also work can be done to standardize the mechanism for sharing the information with the clients because currently clients have their own proprietary way of reporting/receiving information from an AP/any other server.

Additionally, CableLabs, MSOs and vendors may consider working together to enable web services at the South Bound Interface (SBI) of the SON server.