Operational Monitoring and Measurement Challenges in Large Scale WiFi Networks

Hirochika Asai
University of Tokyo

Masafumi Oe
National Astronomical Observatory of Japan

Keiichi Shima
IIJ Innovation Institute

ABSTRACT

We present our trials of WiFi monitoring and measurement with the currently implemented technologies in large-scale WiFi network operations. We then discuss the lacking technologies for the operators, regarding to the three WiFi network-specific challenges; 1) handling the mutable client behavior due to the mobility, 2) monitoring spatio-temporal radio resource utilization, and 3) analyzing the interference on the shared resource. We believe the discussion and the practical problems raised in this paper will contribute the future design of monitoring standards and architectures.

1. INTRODUCTION

The Internet has become an essential infrastructure. The emergence technology to provide end-users with the Internet access is wireless such as WiFi (i.e., IEEE 802.11) and cellular data network (e.g., 3G/LTE). Since cellular data networks are expensive than WiFi networks with wired upstream connectivity, public WiFi networks have been deployed to offload the cellular data traffic [8]. WiFi networks are also deployed at conferences and events to provide the Internet access to the participants. Therefore, the operation technology of WiFi networks increasingly gains its importance to provide good quality connectivity.

However, the operations of WiFi networks, especially large-scale networks, are still troublesome and challenging for operators due to the lack of monitoring and measurement schemes. Unlike in well-matured wired networks, the monitoring and measurement in WiFi networks are challenging for the following three reasons: 1) Clients are mutable due to the mobility. In the wired networks, the statistics such as byte and packet counters of each client are monitored at a port of the end switches. However, the mobility of the clients in WiFi networks makes it difficult to capture the statistics of each client. 2) The resource capacity is not represented as fixed bandwidth (i.e., bytes per second) but as time (i.e., (nano)seconds). In the wired network, for example, the utilization to the capacity can be calculated from the byte counters because the link speed is fixed and does not dynamically change. However, the link speed (transmit rate) dynamically changes in the WiFi networks. Therefore, we cannot see how much percentage of the resource is currently utilized by monitoring the byte and packet counters. 3) The resource is not exclusive, meaning that the resource is shared among other services and radio, and it interferes with them. Thus, we cannot utilize the 100% of the resource capacity.

The authors have worked on large-scale conference networks such as symposiums of WIDE Project [4] and IETF meetings [3]. In this paper, we present our trials of WiFi monitoring and measurement with the currently implemented technologies in large-scale WiFi network operations. We then discuss the lacking technologies for the operators, regarding to the three challenges pointed out above. We believe the discussion and the practical problems raised in this paper will contribute the future design of monitoring standards and architectures.

2. CONVENTIONAL MONITORING

Both in the wired and wireless network, the network operators have monitored the statistics through the standardized protocol, Simple Network Management Protocol (SNMP). The data model for the statistical values and the other data such as configurations is defined as a Management Information Base (MIB) module. Network facilities implement an SNMP agent and relevant MIB modules to provide access to these data for management tools. Since the monitoring architecture with SNMP is based on polling, the statistical values are mainly defined as counters such as byte and packet counters that yield average byte (bit) and packet rates. Some values are defined as current values such as link status and speed (e.g., 1000 Mbps/full-duplex). These values are polled from a management tool, typically with the five minute interval. Although the interval setting highly depends on the spec of the facility running the SNMP agent and the monitoring tool, the operators merely use the interval less than five minutes. This is because SNMP allows an agent to reply cached information and some SNMP agents update the cache in the five minute granularity. Here, one problem with the standardized MIB modules, only aggregated traffic per radio interface (i.e., 2.4 GHz and 5 GHz bands) or access point is monitored using the IF-MIB [11]. As previously described, the resource capacity in WiFi networks is not fixed bandwidth because the WiFi stations utilize various transmit rate. Therefore, the aggregated traffic does not represent how much resource is actually used.

Researchers have collected other data to analyze the characteristics of WiFi networks. Asai et al. [5] captured CAPWAP [7] packets that encapsulate the IEEE 802.11 data frames between a controller and access points. They estimated the transfer duration from the frame length extracted from CAPWAP packets and the transmit rate obtained via SNMP with non-standardized enterprise MIB modules to characterize IEEE 802.11 a/b/g/n by the packet intervals. The transfer duration is useful to calculate the utilization to the resource capacity. However, as pointed above, the SNMP agent is allowed to respond cached information. Therefore, the estimation accuracy depends on the granularity of the polled data.

Joel et al. [12] employed an active measurement approach with crowd-sourcing. They analyzed the performance of cellular and WiFi networks at metropolitan areas using the measured large-scale dataset. The advantage of their approach is that the active measurement shows the effective throughput and end-user performance. However, their approach requires end-user cooperation in the operating networks. In practice, we are required to monitor the statistics at the boundary between the infrastructure and clients from the infrastructure side because it is a responsibility demarcation point between operators and users. Another possibility is that the operators might deploy probes to conduct the active measurement, but it costs much to cover the large-scale networks.

From the view point of the layer 1, physical layer, the use of spectrum analyzers is the solution to reveal the actual resource utilization. However, the site survey with spectrum analyzers is more expensive than the active measurement. Therefore, they are usually used in the design and deployment phase of a WiFi network and the operation phase in case that a fault or a problem continuously occurs.

2.1 Preliminary Field Trial

We have tried to monitor more fine-grained information on the WiFi network with a lightweight approach, using SNMP. Although standardized MIB modules to monitor the detailed statistics do not currently exist, recent WiFi access points and controllers implement enterprise MIB modules that provide per-client statistics as collected in Ref. [5]. We developed a tool to monitor these per-client statistics via SNMP; the collected data are SSID, BSSID, client MAC address, supported transmit rate list, current transmit rate, channel, RSSI, transmitted and received packet and byte counts, and association duration. We set up the polling interval to five minutes with consideration for the cache behavior of the SNMP agent. With this tool, we conducted a WiFi network operation in the biannual symposium of the WIDE project [4] in 12–15 March 2015. The WiFi network of the symposium consisted of ten access points with one controller (Cisco Wireless Controller 5508).

Figure 1 shows the number of associations for each access point. This information has been considered useful to estimate the channel utilization and the processor load of the access points. It is also useful to adjust the coverage of each access point with the radio power configuration. However, this information ignores the different resource utilization between active and inactive (e.g., in a sleeping state) clients. Therefore, we cannot determine whether the resource actually reaches the limitation from this information. Thus, we need other metrics for troubleshooting when problems such as bad quality in performance are reported.

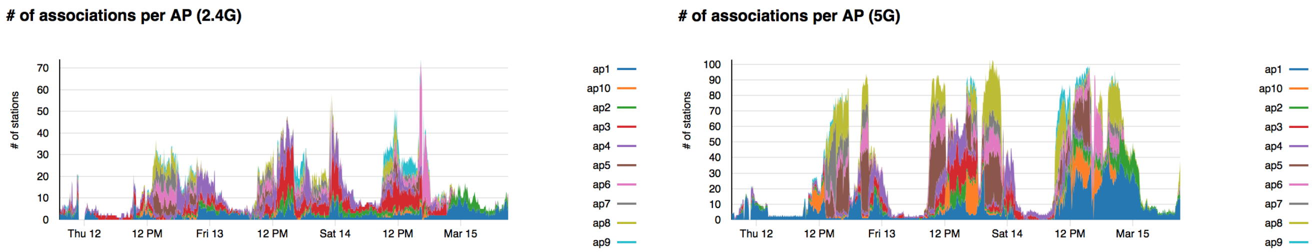
Figure 2 depicts the traffic volume of each access point during the symposium. This is much familiar to the operators of wired networks. However, since this information does not take into account the transmit rate, this figure does not show the actual radio resource utilization. Consequently, this figure is nothing than eye-catching visualization in the operations of WiFi networks. In the real WiFi network operations, we experienced a case that this information does not help; we observed high radio resource utilization due to massive multicast traffic although the traffic volume was not high (not at the spikes in Figure 2). This was because the broadcast and multicast traffic were delivered with the minimum transmit rate (i.e., taking a long time for delivery), and thus consumed radio resource much.

Thanks to the enterprise MIB modules implemented in the controller, we can monitor more detailed information such as per-client statistics. The detailed information allows the operators to investigate the network status in detail. For example, if a client experiences bad quality, the operators look at the monitored RSSI and packet and byte count history to investigate whether the problem is caused at the client side, the WiFi infrastructure, or the upstream wired network. It is also possible to estimate the radio resource utilization from the transmit rate and the CAPWAP packet trace as done in Ref. [5]. However, it is definitely high cost to capture the CAPWAP packets and analyze them with the transmit rate obtained via SNMP. Moreover, IEEE 802.11n/ac dynamically changes the transmit rate for better throughput. It requires shorter polling interval to yield good estimation accuracy. Therefore, it is still challenging to measure the radio utilization with a lightweight approach.

2.2 Upcoming Field Trial

We will work on network operations in a global event, the 23rd World Scout Jamboree [1], and an international meeting, the 94th IETF meetings [2]. In the 23rd World Scout Jamboree we will deploy a relatively large-scale WiFi network; 33,000 people participate in and more than 5,000 clients are expected to concurrently associate to the WiFi network. In this kind of large-scale networks, the measurement and monitoring are significantly important to provide a stable and good quality network with minimal operators interactions to end users.

To investigate which information is really useful in operations, we will monitor and measure more detailed information in this event. We plan to capture the packet trace in addition to the WiFi association information. We also plan to



(a) 2.4 GHz (b) 5 GHz

Figure 1: The number of associations for each access point.

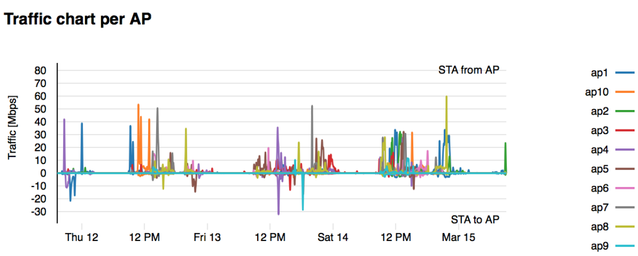


Figure 2: Temporal chart of the traffic volume of each access point.

conduct some active measurements. In near future, we will conduct further analysis on the large-scale WiFi network and discuss the measurement and monitoring tools and architecture for the large-scale WiFi network operations.

3. CHALLENGES

In this section, we discuss the industrial, operational, and research challenges of monitoring and measurement in WiFi network operations to fill the gap between operations and research. In the industrial and operational challenges, we discuss the information that cannot be obtained from the WiFi network facilities but considered useful for the operations. We also discuss research challenges towards the troubleshooting automation in WiFi network operations.

3.1 Industrial and Operational Challenges

In Section 1, we pointed out three WiFi network-specific challenges; 1) handling the mutable client behavior due to the mobility, 2) monitoring spatio-temporal radio resource utilization, and 3) analyzing the interference on the shared resource.

The first challenge is almost solved by using enterprise MIB modules. The enterprise MIB modules enables us to monitor per-client statistics. A remaining problem is that some values that dynamically change such as RSSI and transmit rate are difficult to be precisely analyzed in polling-based monitoring. Another problem is that these MIB modules are not standardized. Standardization is quite important in the real operations to use the same mechanism and tools for different vendors of facilities.

The estimation of radio resource utilization from the transmit rate and the CAPWAP packet trace solves the second challenge [5]. However, as discussed in the previous section, it requires the frequent polling interval and the high cost capturing and computation procedure.

The third challenge has not been taken into account in the MIB modules. The active measurement [12] and spectrum analyzers would give some intuitive ideas on the interference for network operators. However, these on-site surveys cost much in large-scale networks.

Thus, we are still lacking of the intuitive information related to radio utilization and interference. We think the following statistical counters in the WiFi facilities help the operators; 1) accumulated transmit duration, 2) retransmission counters, and 3) accumulated backoff time. Although the first misses the radio utilization of some dropped frames from clients to access points due to the collisions and the interference, it is approximated to the radio utilization. The others are known as the metrics of the collisions and the interference. These statistical values can be monitored at the infrastructure side. Therefore, it can be deployed easier than developing a cooperative way to collect the statistical information from clients.

Another operational challenge is the user interface to the operators and visualization of the monitored and measured data. In the previous section, we have illustrated the data on temporal charts because they are commonly used to show the current status and the temporal trends. However, they are not good to present short-period events such as temporary failures and anomalies. We will seek for the better user interfaces and visualization through the future trials.

3.2 Research Challenges

From the viewpoint of research, the lacking information in the MIB modules might be estimated using the packet interarrival time from the packet trace captured at the wired networks [14, 6, 5]. It would be great if this could be achieved and this is a research challenge.

Advanced research challenge after the successful measurement and monitoring of the data on per-client statistics, radio utilization, and statistical values influenced by the interference such as retransmission counters and accumulated backoff time is the automation of troubleshooting of WiFi networks since it is one of the most distressing tasks and requires the expert knowledge. The automated troubleshooting and diagnostics have been researched in wired networks [10, 9]. Diagnostics on WiFi access points have also been researched [13]. However, no research has been focused on the WiFi networks including the quality of service. Thus, it is really challenging and vital against the penetration of large-scale WiFi networks such as public WiFi.

4. CONCLUSION

We presented our trials of WiFi monitoring and measurement with the currently implemented technologies in large-scale WiFi network operations. From our trials, we are still lacking of the intuitive information related to radio utilization and interference. Our suggestion is to have some statistical counters in a MIB module to capture the radio utilization and interference, such as accumulated transmit duration, retransmission counters and backoff time in the WiFi facilities.

5. REFERENCES

[1] 23rd World Scout Jamboree. http://www.23wsj.jp.

[2] IETF 94 Yokohama. http://www.ietf.org/meeting/94/index.html.

[3] The Internet Engineering Task Force (IETF). http://www.ietf.org/.

[4] WIDE Project. http://www.wide.ad.jp/.

[5] H. Asai, K. Fukuda, and H. Esaki. Towards characterization of wireless traffic in coexisting 802.11a/g and 802.11n network. In *Proceedings of the ACM CoNEXT Student Workshop*, CoNEXT '10 Student Workshop, pages 1:1–1:2, New York, NY, USA, 2010. ACM.

[6] V. Baiamonte, K. Papagiannaki, and G. Iannaccone. Detecting 802.11 wireless hosts from remote passive observations. In *NETWORKING 2007. Ad Hoc and Sensor Networks, Wireless Networks, Next Generation Internet*, volume 4479 of *Lecture Notes in Computer Science*, pages 356–367. Springer Berlin / Heidelberg, 2010.

[7] P. Calhoun, M. Montemurro, and D. Stanley. Control And Provisioning of Wireless Access Points (CAPWAP) Protocol Specification. RFC 5415 (Proposed Standard), Mar. 2009.

[8] K. Fukuda, H. Asai, and K.-i. Nagami. Tracking Evolution of Diverse Network Usages of Smartphones. In *IMC '15*. ACM, 2015.

[9] A. Mahimkar, Z. Ge, J. Wang, J. Yates, Y. Zhang, J. Emmons, B. Huntley, and M. Stockert. Rapid detection of maintenance induced changes in service performance. In *Proceedings of the Seventh COnference on Emerging Networking EXperiments and Technologies*, CoNEXT '11, pages 13:1–13:12, New York, NY, USA, 2011. ACM.

[10] A. A. Mahimkar, Z. Ge, A. Shaikh, J. Wang, J. Yates, Y. Zhang, and Q. Zhao. Towards automated performance diagnosis in a large iptv network. In *Proceedings of the ACM SIGCOMM 2009 Conference on Data Communication*, SIGCOMM '09, pages 231–242, New York, NY, USA, 2009. ACM.

[11] K. McCloghrie and F. Kastenholz. The Interfaces Group MIB. RFC 2863 (Draft Standard), June 2000.

[12] J. Sommers and P. Barford. Cell vs. WiFi: On the performance of metro area mobile connections. In *Proceedings of the 2012 ACM conference on Internet measurement conference*, IMC '12, pages 301–314, New York, NY, USA, 2012. ACM.

[13] S. Surana, R. Patra, and E. Brewer. Simplifying fault diagnosis in locally managed rural wifi networks. In *Proceedings of the 2007 Workshop on Networked Systems for Developing Regions*, NSDR '07, pages 1:1–1:6, New York, NY, USA, 2007. ACM.

[14] W. Wei, B. Wang, C. Zhang, J. Kurose, and D. Towsley. Classification of access network types: Ethernet, wireless lan, adsl, cable modem or dialup? *Comput. Netw.*, 52(17):3205–3217, 2008.