# Understanding the Impact of AP Density on WiFi Performance Through Real-World Deployment

Kaixin Sui, Siqi Sun, Yousef Azzabi, Xiaoping Zhang, Youjian Zhao, Jilong Wang, Zimu Li, Dan Pei

Enterprise Wireless LAN (EWLAN)

- EWLAN is an important infrastructure for public WiFi usage in universities, companies, shopping malls, *etc.*

School, University, Shopping Centre,
Hospital or Hotel
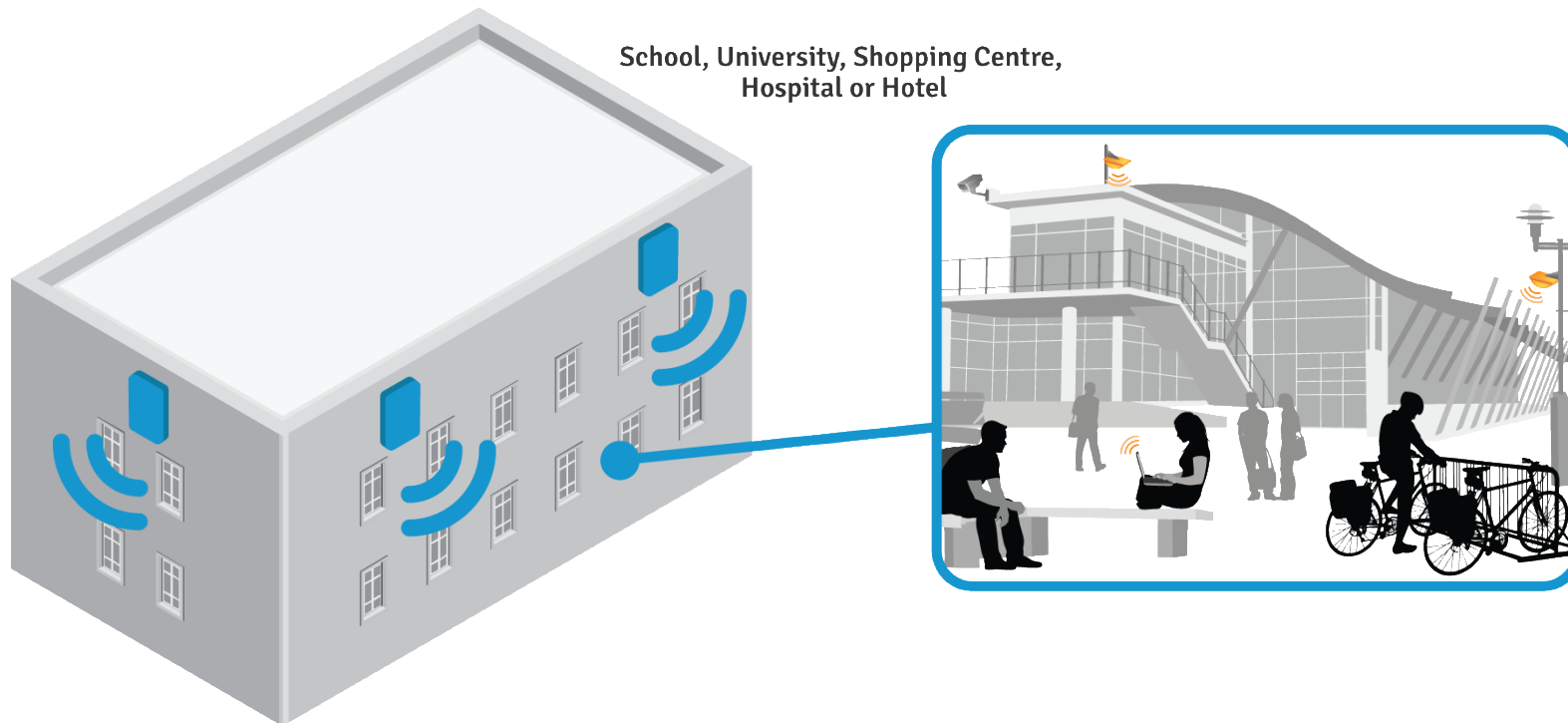
► Poor performance of EWLAN

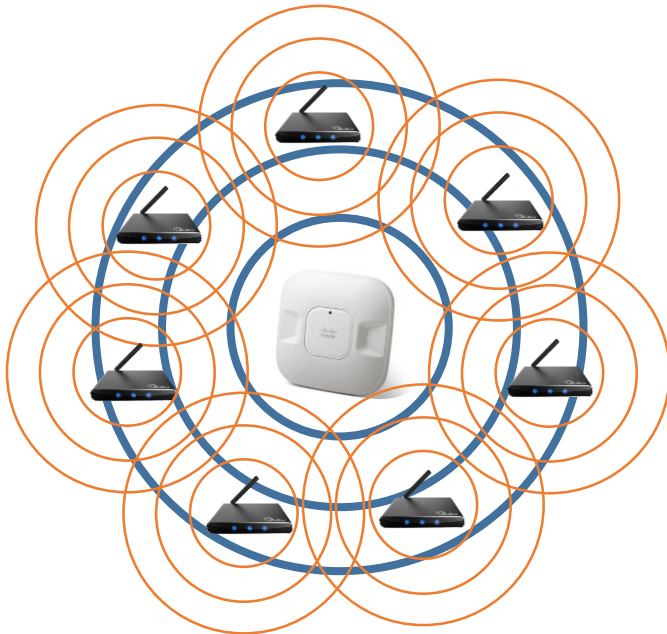- However, poor performance of the EWLAN is not uncommon.

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- Two common reasons
    1. Interference from rogue Aps
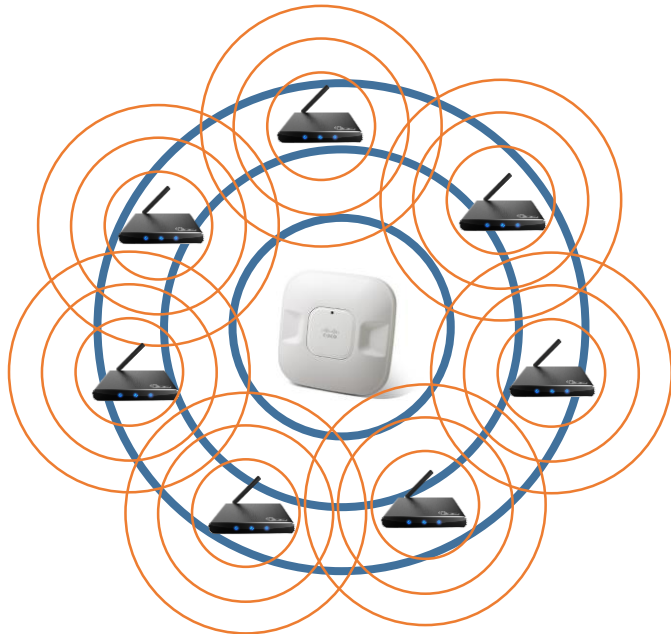
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- Two common reasons
    1. Interference from rogue Aps
    2. Over-utilization

Poor performance of EWLAN

- Two intuitively promising solutions
    1. Disable the wired Internet access to eliminate the rogue APs
    2. Increase the enterprise AP deployment density to increase the capacity of the EWLAN infrastructure

It is actually challenging to decide the deployment density that works the best for a set of real-world users.

▶ Poor performance of EWLAN

- Two intuitively promising solutions

  1. Disable the wired Internet access to eliminate the rogue APs

  2. Increase the enterprise AP deployment density to increase the capacity of the EWLAN infrastructure

It is actually challenging to decide the deployment density that works the best for a set of real-world users.

  1. The deployment should be dense enough

  2. Higher density means higher deployment cost

  3. There are only limited number of orthogonal channels

▶ Large-scale real-world deployment

- To study the impact of enterprise AP density on WiFi performance, about 800 enterprise APs are deployed on **Tsinghua campus**.

- 4 km^2
- 42,000 students
- 11,000 faculty and staff

▶ Large-scale real-world deployment

- To study the impact of enterprise AP density on WiFi performance, about **800 enterprise APs** are deployed on Tsinghua campus.
  - 6 WiFi networks
  - 3 AP density levels (Dense, less dense, and sparse)
  - 4 enterprise AP vendors (Cisco, H3C, Aruba, and Ruckus)
  - Each of the networks has more than 100 enterprise APs

Larger scale　　　　Realistic traffic

Large-scale real-world deployment

- 6 WiFi networks

Density	Dense	Dense	Dense	Less dense	Less dense	Sparse
Network	1	2	3	4	5	6
Vendor	Cisco	H3C	Aruba	Aruba	Ruckus	Cisco
1 AP for	1 Room	1 Room	1 Room	2 Rooms	2 Rooms	>10 Rooms
Rogue exists?	No	No	No	No	No	Yes
Total #AP	156	133	124	108	170	165
#Student per room	2	2	2	3	3	>5

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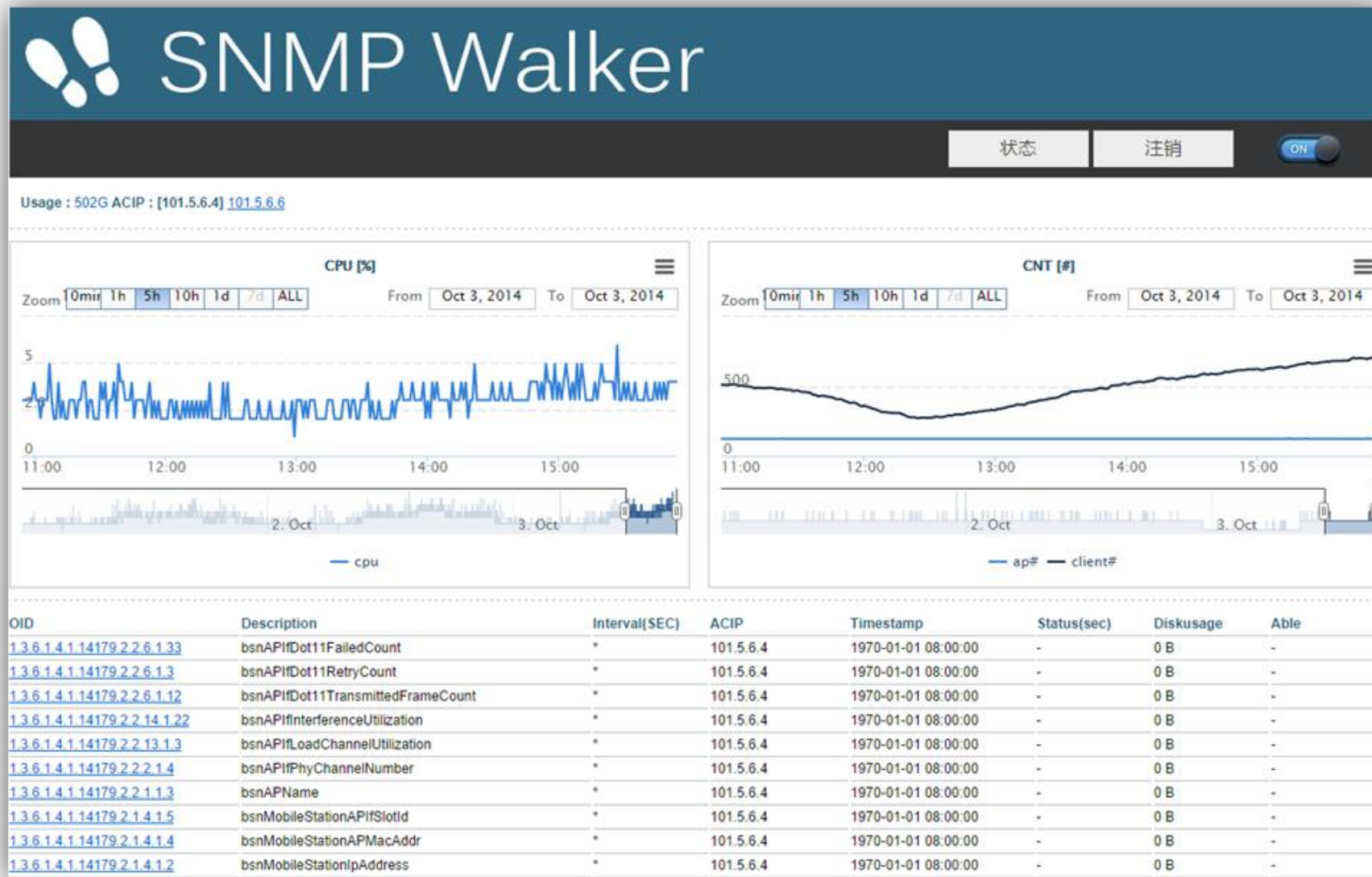| Density	Dense	Dense	Dense	Less dense	Less dense	Sparse
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Data collection

- Collect the SNMP Data without any additional measurement hardware
  - Client SNR
  - Interference ratio
  - Loss rate
  - Throughput

TABLE I
SNMP DATA SET.

Object	Description	Cisco OID	H3C OID	Aruba OID	Ruckus OID
1	This counter shall increment when an MSDU is not transmitted successfully	bsnAPIfDot11-FailedCount	h3cDot11FailedCnt	N/A	ruckusZDWLANAP-RadioStatsTxFail
2	The number of attempts made by the EAP before transmitting the MSDU successfully	bsnAPIfDot11-RetryCount	h3cDot11RetryMSDUCnt	N/A	ruckusZDWLAN-StaRetries
3	This counter shall increment for each successfully transmitted MSDU	bsnAPIfDot11-TransmittedFrameCount	N/A	N/A	N/A
4	Time percentage used by interference from other 802.11 networks on this channel	bsnAPIf-InterferenceUtilization	N/A	wlanAPCh-InterferenceIndex	N/A
5	Time percentage used by all non WiFi and WiFi traffic of current channel	bsnAPIf-LoadChannelUtilization	N/A	wlanAPRadioUtilization	ruckusZDWLANAP-RadioStatsResourceUtil
6	Number of clients associated with this radio	bsnApIfNoOfUsers	h3cDot11AP-UserAuthCurNumber	wlanAPRadio-NumAssociatedClients	ruckusZDWLANAP-RadioStatsNumSta
7	Name assigned to this AP	bsnAPName	h3cDot11CurrAPName	wlanAPName	ruckusZDAP-ConfigDeviceName
8	802.11 MAC address of the AP to which the client is associated	bsnMobileStation-APMacAddr	N/A	N/A	ruckusZDWLAN-StaAPMacAddr
9	The number of bytes sent by this station	bsnMobileStation-BytesSent	h3cDot11Station-TxDataFrameCnt	wlanStaTxBytes	ruckusZDWLAN-StaTxBytes
10	IP Address of the Mobile Station	bsnMobileStation-IpAddress	h3cDot11Station-IPAddress	wlanAPIpAddress	ruckusZDWLAN-StaIPAddr
11	Average packet RSSI for the Mobile Station	bsnMobileStationRSSI	h3cDot11StationRSSI	wlanStaRSSI	ruckusZDWLAN-StaAvgRSSI
12	The difference between signal strength of the client and noise	bsnMobileStationSnr	h3cDot11StationRxSNR	StaSNR	N/A
13	The SSID Advertised by Mobile Station	bsnMobileStationSsid	h3cDot11Station-SSIDName	wlanSta-AccessPointESSID	ruckusZDWLAN-StaSSID
14	The throughput achieved on this channel	N/A	N/A	wlanAPChannel-Throughput	N/A
15	The current power level of the radio	N/A	N/A	wlanAPRadio-TransmitPower	ruckusZDWLANAP-RadioStatsTxPower
16	The number of retry packets as a percentage of the total packets transmitted and received by this station	N/A	N/A	wlanStaFrameRetryRate	ruckusZDWLANAP-RadioStatsFrameRetryRate

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$$LossRate = \frac{FailCount + RetryCount}{FailCount + RetryCount + SuccessCount}$$

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- **We compare different network deployment schemes to show**

  1. The improvement if we increase the density and eliminate the rogue APs

  2. The performance of different density levels

  3. The difference of AP vendors

▶ Dense vs. sparse

Density	Dense	Sparse
Network	**1**	**6**
Vendor	Cisco	Cisco
1 AP for	1 Room	>10 Rooms
Rogue exists?	No	Yes
Total #AP	156	165
#Student per room	2	>5
Client SNR	👍	
Interference ratio	👍	
Loss rate	👍	

- **Observation**
  - Dense deployment has higher SNR, lower interference, and lower loss rate than sparse deployment
  - **In general higher AP density improves WiFi performance**

Dense vs. less dense

| Density	Dense	Less dense
Network	3	4
Vendor	Aruba	Aruba
1 AP for	1 Room	2 Rooms
Rogue exists?	No	No
Total #AP	124	108
#Student per room	2	3
Client SNR	👍	
Interference ratio		👍
Loss rate		👍
Throughput		👍

- **Observation**

- Denser deployment has less client numbers per each enterprise AP, higher client SNR, but higher interference ratio, higher loss rate, and lower throughput than less dense deployment

- **Therefore, over-dense deployment with unnecessarily high transmission power can worsen WiFi performance**
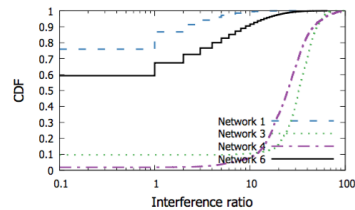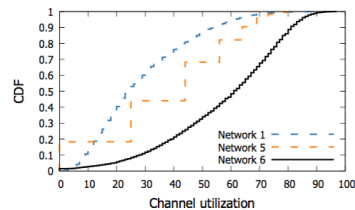
▶ Different vendors
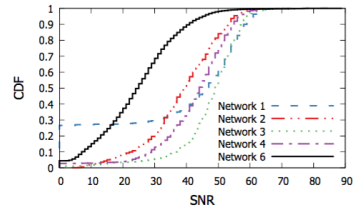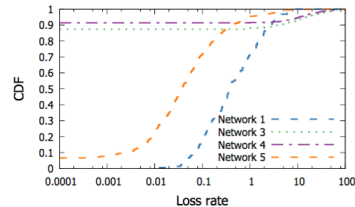
Fig. 5. Different Vendors.

- **Observation**

- The choice of AP vendor has an impact on the WiFi performance.

  - Aruba has a lower loss rate than Ruckus and Cisco

  - Cisco has a less interference ratio that Aruba

▶ Conclusion

- A large-scale real-world deployment to study the impact of enterprise AP density on WiFi performance.

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- 3 main observations
  1. In general, higher AP density improves WiFi performance
  2. Over-dense deployment with unnecessarily high transmission power can worsen WiFi performance
  3. Choice of AP vendors also has an impact on WiFi performance

Thank you!

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