Why it takes so long to connect to a WiFi access point

Pei, C., Wang, Z., Zhao, Y., Wang, Z., Meng, Y., Pei, D., Peng, Y., Tang, W., Qu, X.
IEEE INFOCOM 2017 - Conference on Computer Communications

2023.7.27.
Summarized by, Sangwi Kang | swkang@mmlab.snu.ac.kr

Outline

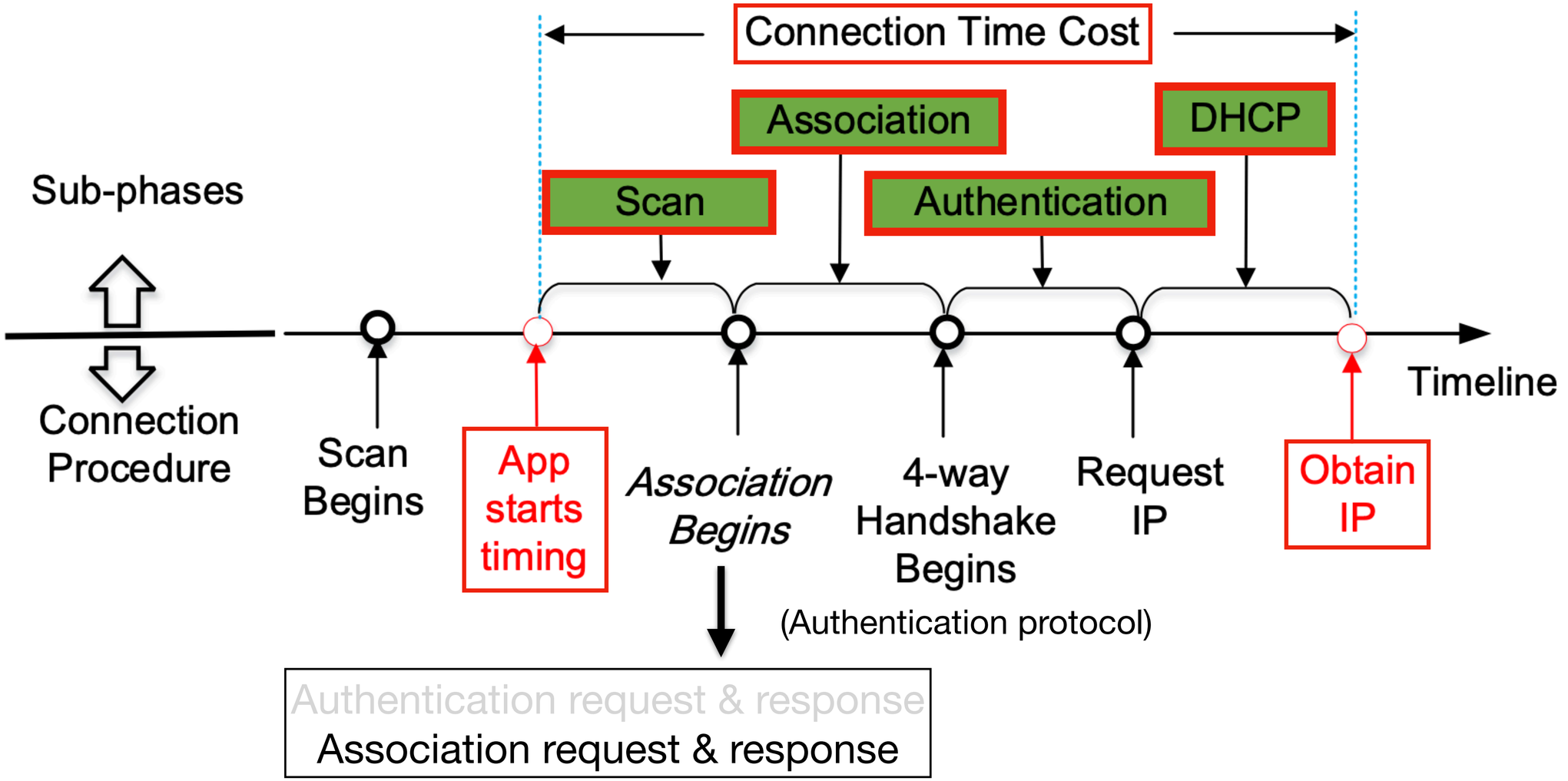
- Overview
- WiFi Set-Up Process Analysis
- Correlation Analysis
- Impacts of Different Mobile Devices and AP Models
- Reducing Connection Time Cost
- Evaluation
- Conclusion

Overview

- In recent years, wireless data traffic has grown exponentially, and the vast majority of it is 802.11 LAN (WiFi) traffic
- However, a lot of WiFi networks show **unsatisfactory results** in terms of **connection success/failure** and **connection time**
- Thus, it is critical to understand the **WiFi connection set-up process** to solve the problems
- In this paper :
  - Analyzing the WiFi connection set-up process
  - Reducing the connection set-up time costs by Machine Learning(ML) based method

WiFi Set-up Process Analysis (1)

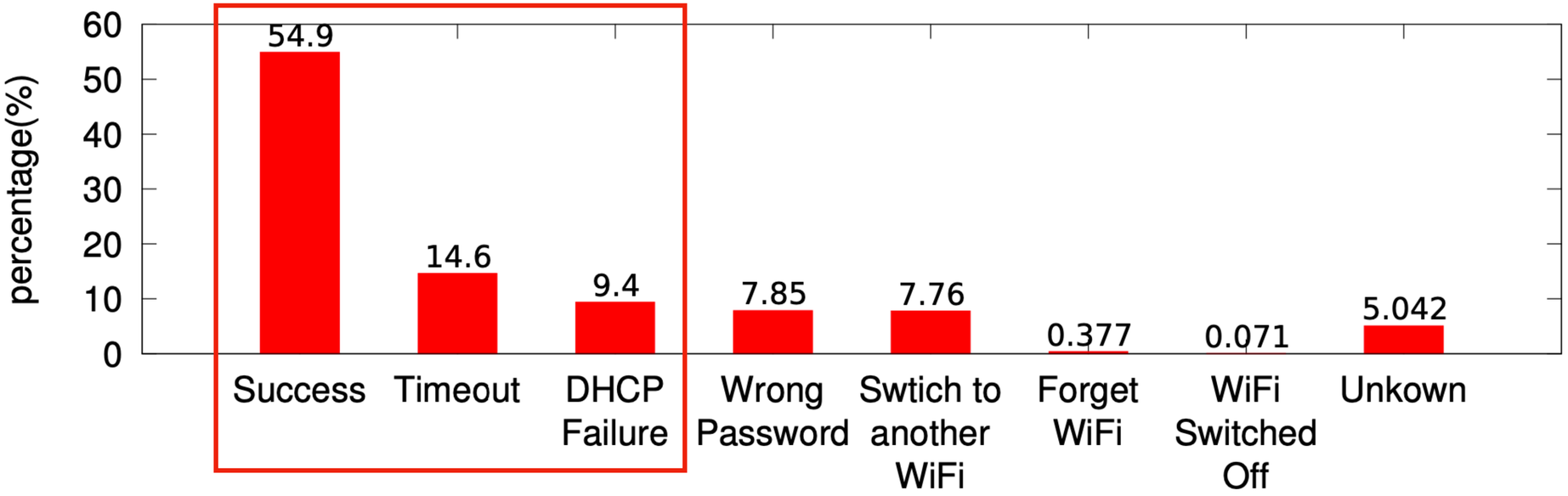
Definitions



WiFi Set-up Process Analysis (2)

WiFi Success & Failure

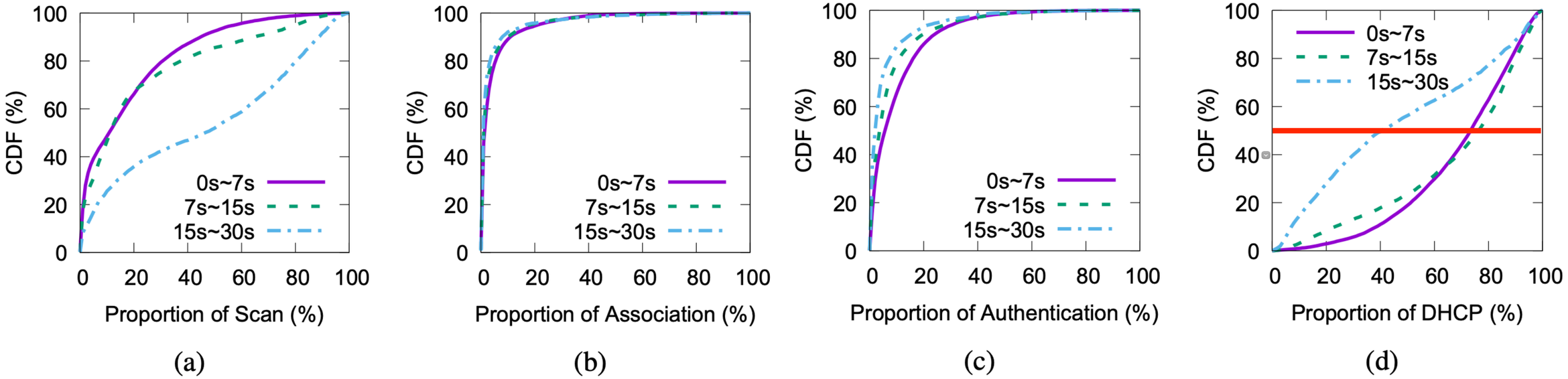
- Success : Successfully **obtained** IP addresses **within 30 sec**
- Timeout : **Not entered** to the *DHCP* phase
- *DHCP* Failure : **Entered** to the *DHCP* phase, but **not obtained** IP addresses



WiFi Set-up Process Analysis (3)

The Distribution of sub-phases

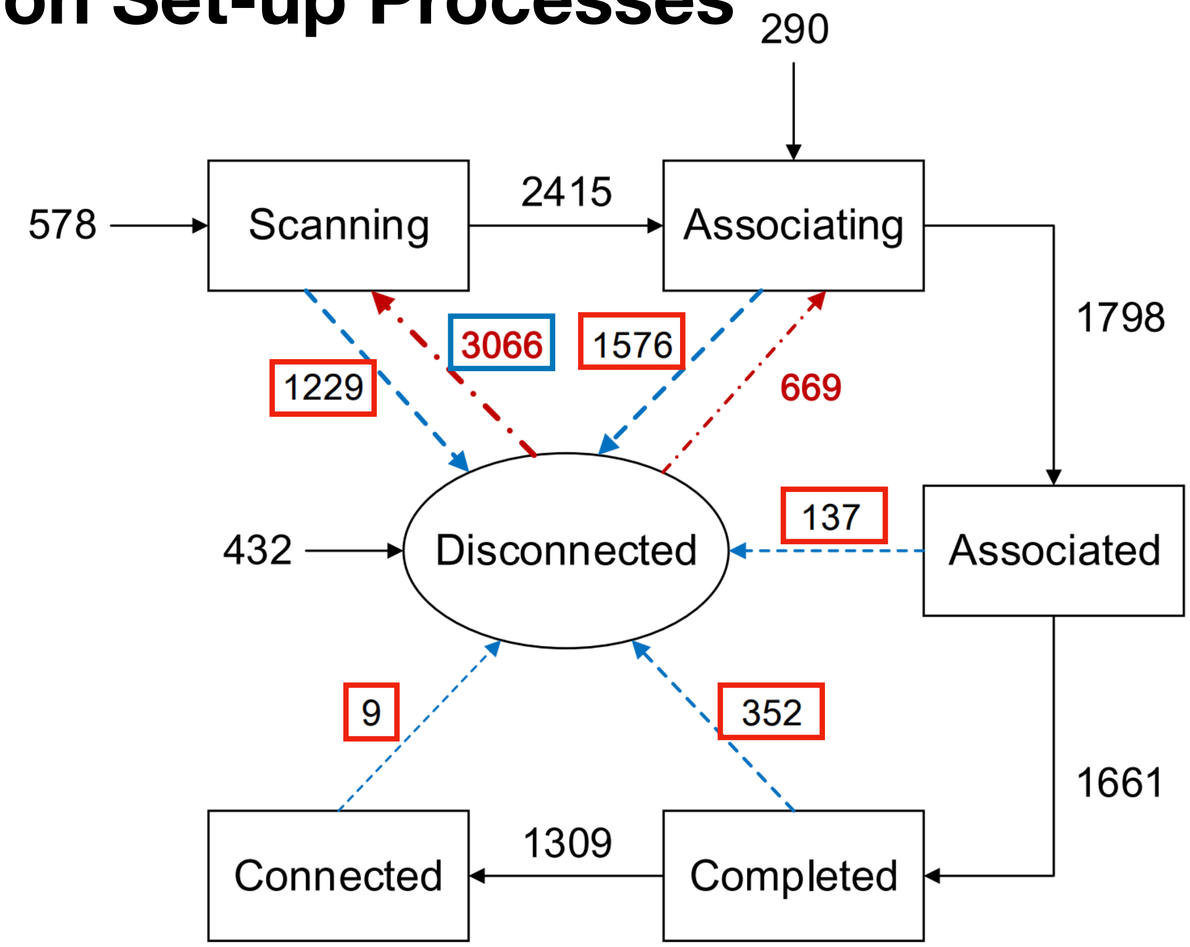
- The *association* and *authentication* sub-phases do not take too much time
- 0~7 sec / 7~15 sec show similar pattern, while **15~30 sec shows different**
- **~15 sec** : the ***DHCP*** phase is higher, **15~30 sec** : the ***Scan*** phase is higher



WiFi Set-up Process Analysis (4)

The State Transition of Connection Set-up Processes

- There are **anomalous state transitions to *Disconnected***
- The *Disconnected* triggers the reconnecting
- The reconnecting starts with Scanning state
- Overall, **multiple times** of the Scanning state entering **increases the *scan* time cost**



Correlation Analysis (1)

Connection Log Dataset Fields

Environment related data

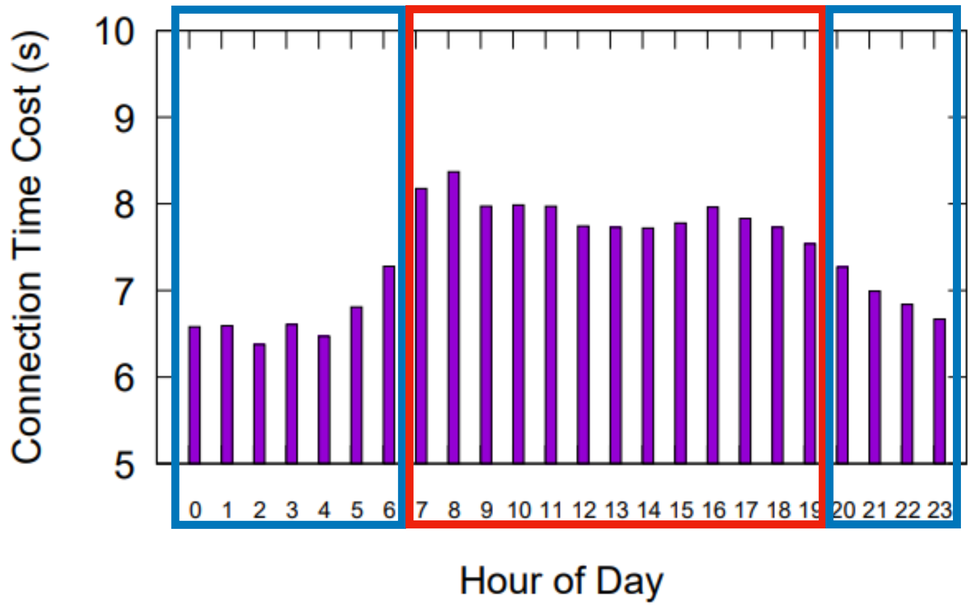
Abbreviation	Features	Description
hour of day	Hour of day.	Which hour the connection event happens in 24 hours.
RSSI	Received Signal Strength Indicator.	The signal strength of AP measured on the mobile device.
number of devices	Number of associated devices.	Number of devices currently associated on the AP.
mobile device model	Mobile device model.	The extracted information from the first eight characters of IMEI.
AP model	AP model.	The extracted information from the first eight characters of AP's BSSID.
Encrypted	Encryption type of the AP.	Whether the AP is encrypted using the password or not, *e.g.*, WPA2.
IsPublic	Is public AP?	The labeling result of an AP to decide whether the AP is public or not.
result	Connection result reported by the App.	Whether the App user successfully connects to the AP or not.
connection time cost	Connection time cost.	The time cost of the connection set-up process.

Performance related data

Correlation Analysis (2)

Qualitative Analysis

- X-Y visualization to show the variance of ***connection time cost*** with **each feature**
- Calculate the mean *connection time cost* for each bin
- Connection time costs in **daytime** are larger than night



Correlation Analysis (3)

Quantitative Analysis

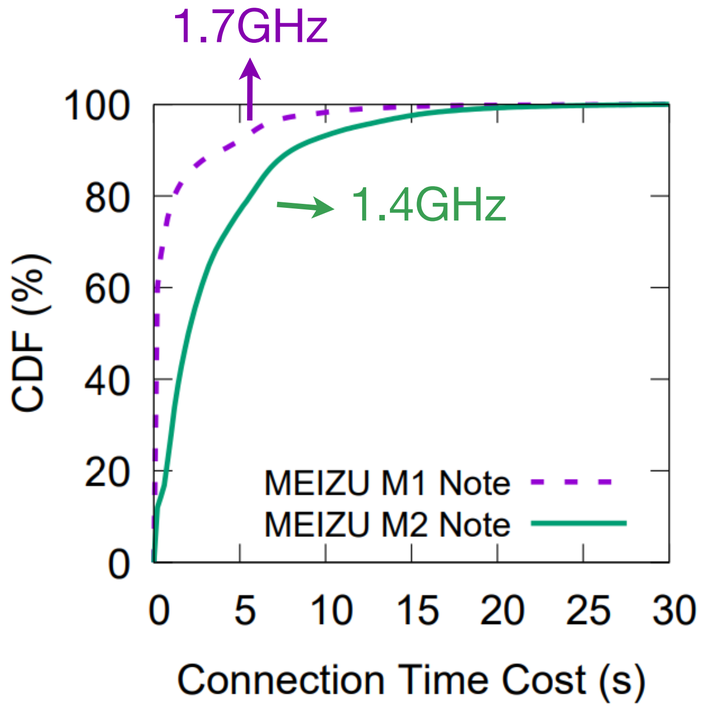
- Relative Information Gain(RIG) and Kendall coefficient(Kendall) to show the relationship of ***connection time cost*** and **each feature**
- **The Model** of mobile device and AP have highest RIG

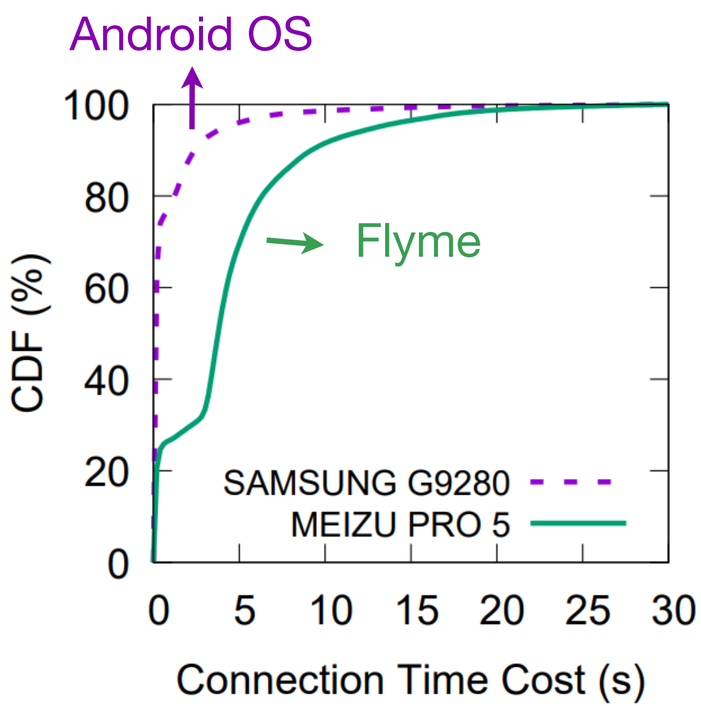
Features	RIG	Kendall
mobile device model	0.156	/
AP model	0.078	/
RSSI	0.020	-0.395
number of devices	0.006	0.208
hour of day	0.005	/

Impacts of Different Mobile Devices and AP Models (1)

Mobile Device Model

- The **chipset** matters : CPU frequency ↑ *connection time cost* ↓
- The **OS** matters

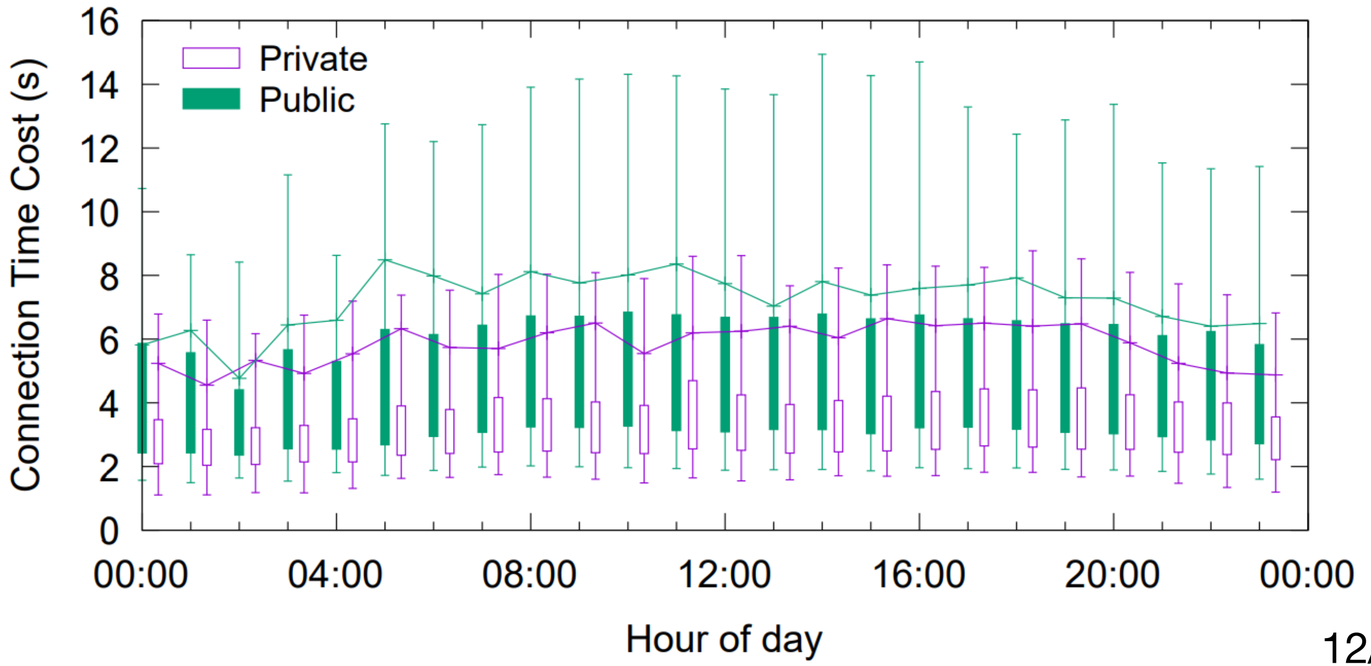




Impacts of Different Mobile Devices and AP Models (2)

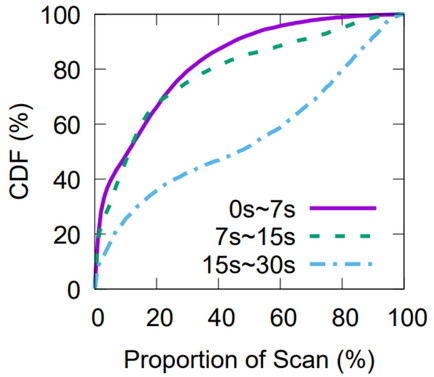
AP Model

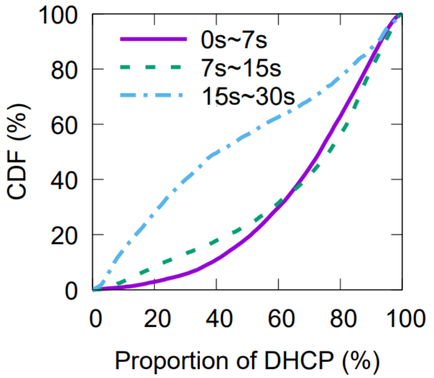
- The *connection time costs* of **public APs** in one day are consistently **larger** than private APs
- Among the 200K APs, there are 2,802 distinct AP models :
  - **27%** are only for **public**
  - **32%** are only for **private**



Reducing Connection Time Cost (1)

Machine Learning Model





- Predict the ***connection time cost*** for **each connection attempt**
- Model : **Random forest**
  - FAST for < 15 sec, SLOW for >15 sec
- Feature : ***Hour of day, RSSI, AP model, mobile device model, Encrypted***
  - *IsPublic* → *AP model*
  - ~~*number of devices*~~

Reducing Connection Time Cost (2)

Machine Learning Based AP Selection Algorithm

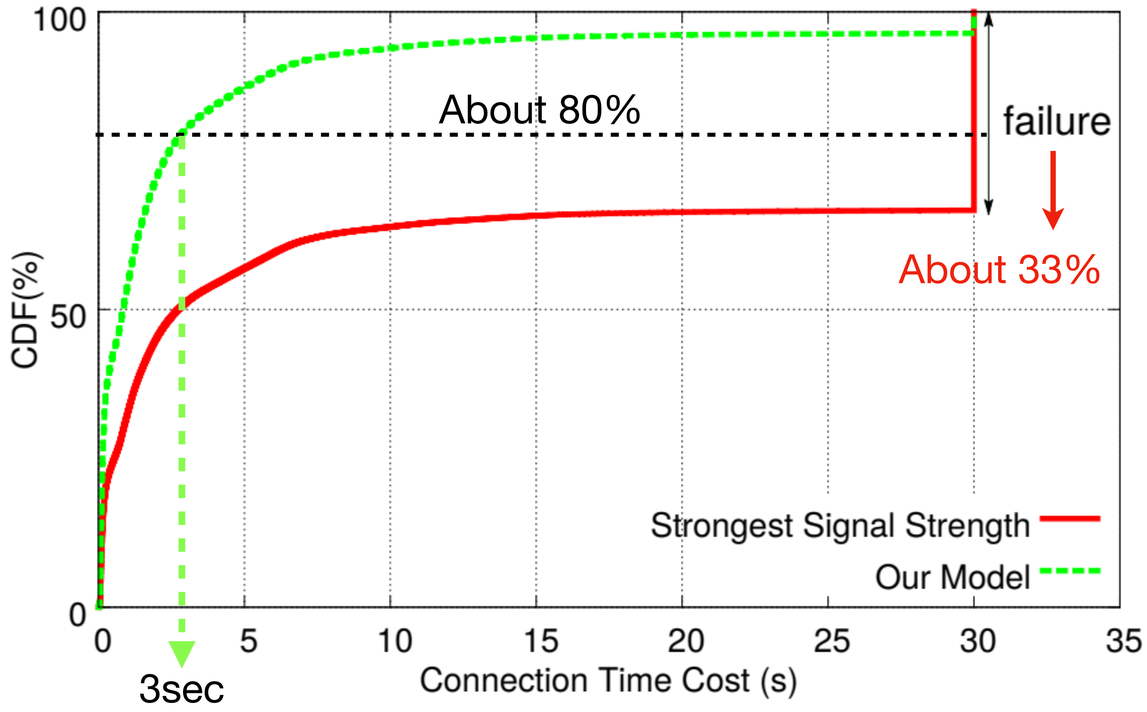
- Help mobile users choose APs **to have lower *connection time cost***

- Step 1 : AP classification
  - Use the trained model to divide APs **into SLOW and FAST sets**
- Step 2 : AP selection
  - Choose the AP with **the strongest signal** from the FAST set

Evaluation

Performance Comparison

- Baseline : Strongest Signal Strength
- In case of ML algorithm :
  - **<u>Less than 3.6%</u>** connection attempts failed
  - The **<u>80%</u>** time costs is only **<u>3 sec</u>**, which is **<u>10X reduction</u>** on the 80% *connection time cost*



Conclusion

- There are a lot of unsatisfactory results in WiFi networks, often due to the *connection time cost*
- Based on the comprehensive and detailed analysis of the *connection time cost*, the ML model is proposed
- And it reduced the connection failure from 33% to 3.6% and the 80% *connection time costs* by 10x

- Extensive, massive data collection and detailed analysis
- Unclear process for collecting dataset
- Need for manual data updates for the proposed algorithm

Appendix (1)
Data Collection Environment

- Connection Log Dataset
  - App : Customized WiFi Manager / Android
  - Duration / Cities : 1 week / 4 different cities
  - Number of unique APs / Devices : 7 million / 5 million
  - The overall number of connection set-up processes : 0.4 billion
- Dataset for Sub-phase Analysis
  - Selected mobile devices : 12,472 devices
  - Connection attempts : 706K

Appendix (2)
Mobile Device Specifications

Average *connection time cost*	Device model	Operating System	Chipset	CPU Frequency	RAM Size	Wireless Interface
475ms	**MEIZU M1 Note**	Flyme	MediaTek 6752	1.7GHz	2GB	IEEE a/b/g/n
754ms	**SAMSUNG G9280**	Android OS	Exynos 7420	2.1GHz	4GB	IEEE a/b/g/n/ac
...	...	...	...	...	...	...
2463ms	**MEIZU M2 Note**	Flyme	MetiaTek 6753	1.3GHz	2GB	IEEE a/b/g/n
3534ms	**MEIZU PRO 5**	Flyme	Exynos 7420	2.1GHz	4GB	IEEE a/b/g/n/ac