

OS Fingerprinting and Tethering Detection in Mobile Networks

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Mobile OS Fingerprinting

□ Problem statement

- Infer what operating system a device is running by analyzing the packets it's generating.
- Tethering detection: identify mobile devices which are sharing the Internet access



Importance

- **Tethering detection**
 - Billing for shared access in mobile networks
- **Security**
 - Policy enforcement in enterprise networks



Existing Works

Application

- HTTP user agent [POf], DHCP options [Satori]

Transport

- TCP handshake, timeout, MTU, flags, init seq. number [POf, NMap, VEYSET02, PAM04, RAID03], TCP Timestamp [INFOCOM99, IMW02]

Network

- IP TTL, ID, dest address [POf, PAM04]

Link

- 802.11 MAC fields, SSID, frame size [MOBICOM07]

Limitation of Existing Works

- Existing works focus on the **Internet traffic**
- **Mobile networks** impose new challenges:
 - Dynamic frequency due to power saving
 - Clock skew, boot time estimation, ...
 - Short connections
 - TCP flavors, initial sequence number, ...
 - Features might have changed in mobile OSes
 - TCP MTU, IP flags, ...

Approach

- Identify features to fingerprint mobile device OSes
- Detect tethering
 - **Clock frequency stability**, boot time estimation
 - IP Time-to-Live, ID Monotonicity
 - TCP timestamp option, **window size scale option**, **timestamp monotonicity**
- Combine multiple features
- Quantify the performance
 - Individual and combined features
 - OS fingerprinting and tethering detection

Dataset

- Lab trace
 - 56 mobile user traces
 - 14 Android phones and tablets traces
 - Samsung Galaxy S5, HTC Ones, HTC Inspire phones, Google Nexus 10 tablet
 - 10 iOS traces
 - iPhone 4s, iPhone5s, iPad 2, iPod Touch
 - iOS 5.1.1, iOS 6.1
 - 32 Windows laptops traces
 - running Windows XP or Windows 7
 - Each capture lasts 10~30 minutes

Other Datasets

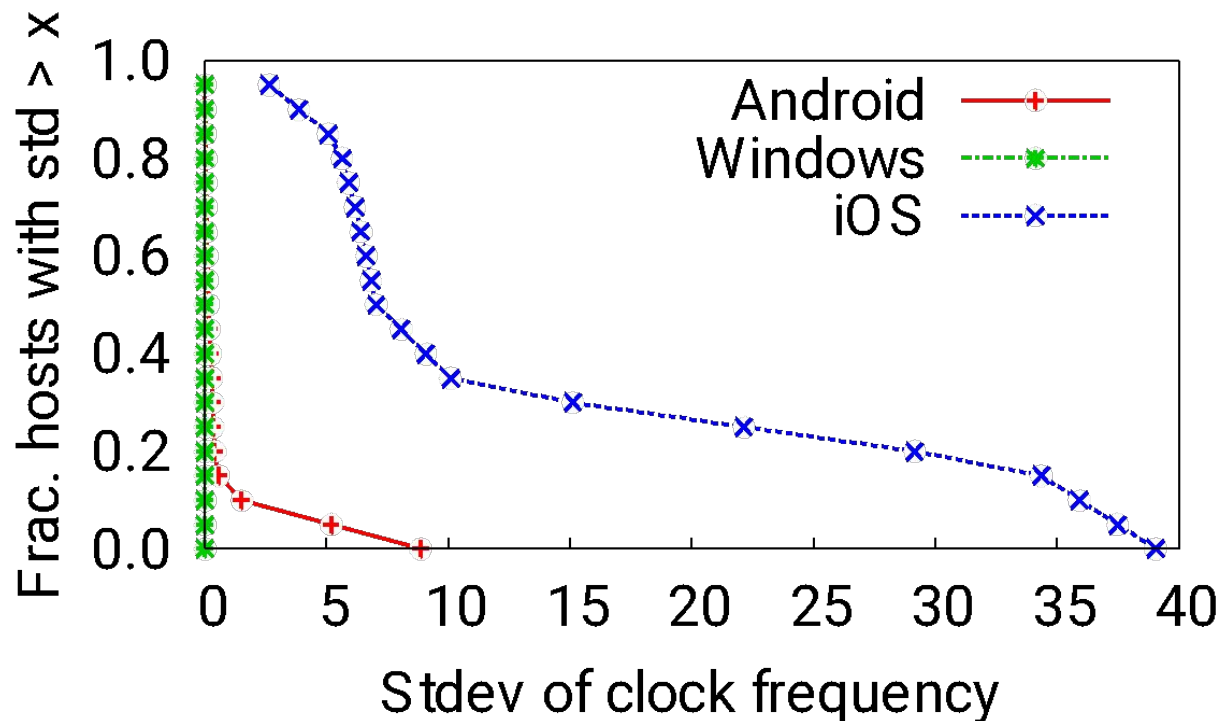
Trace	Time	Duration	# IPs
Lab Trace	Oct. 2013	2 hours	56
SIGCOMM08 Trace	Aug. 2008	1 day	223
OSDI06 trace	Nov. 2006	1 day	292

Features

□ Clock Frequency

$$freq = \frac{timestamp_i - timestamp_1}{rcv_time_i - rcv_time_1}$$

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 - bu
- High clock frequency std. suggests iOS**

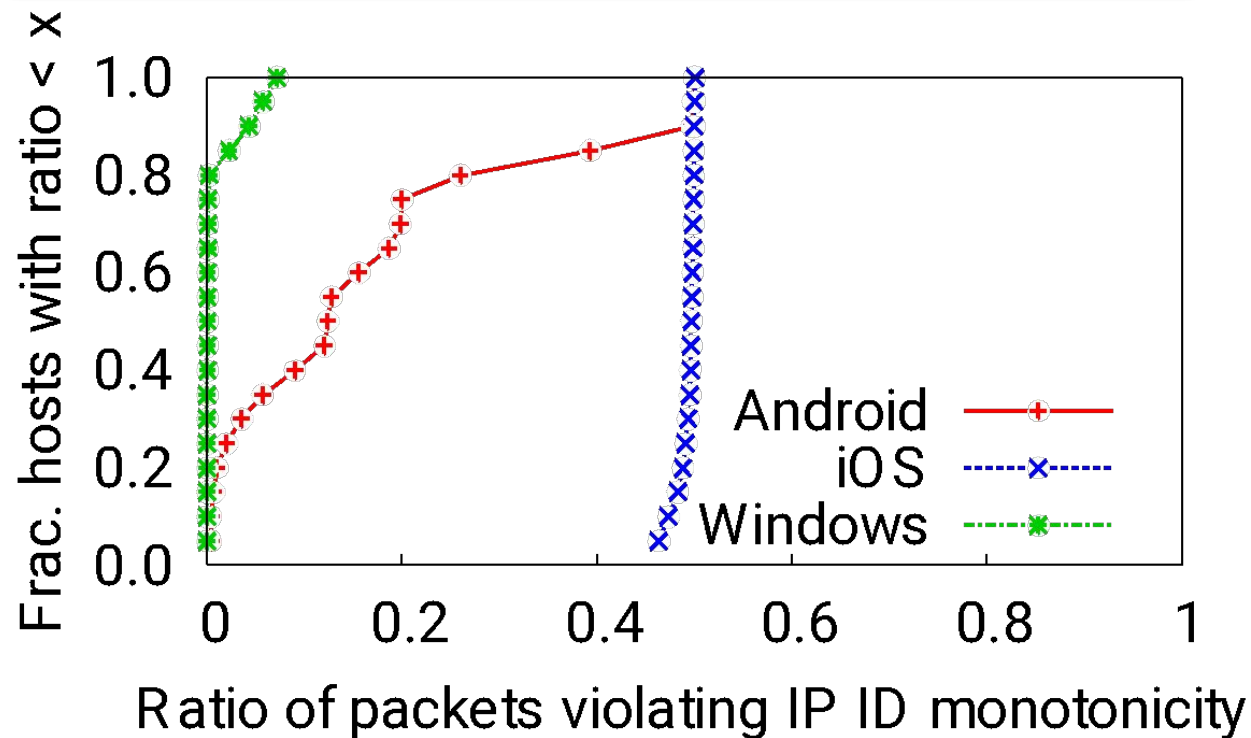


Features

IP ID Monotonicity

Windows

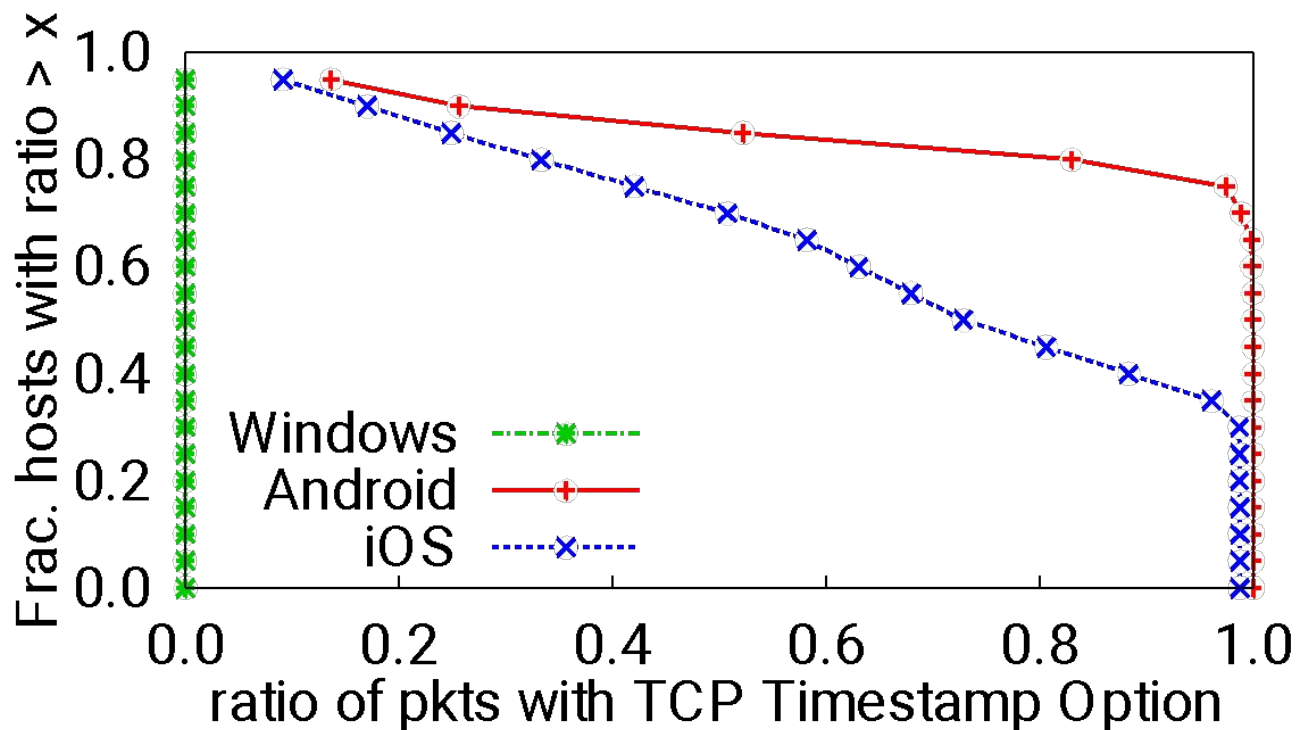
High violation ratio suggests iOS;
low violation ratio suggests Windows.



Features

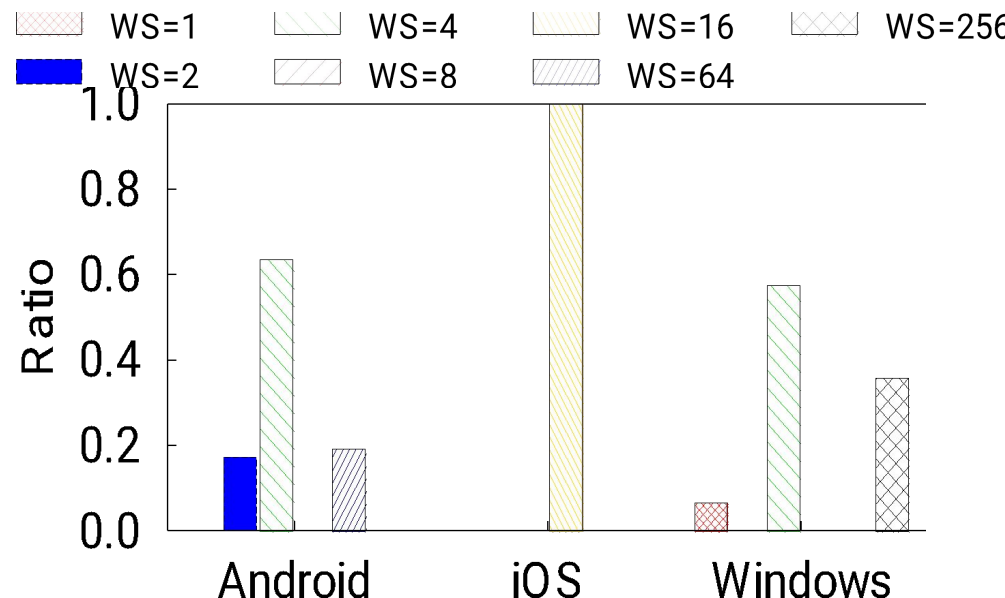
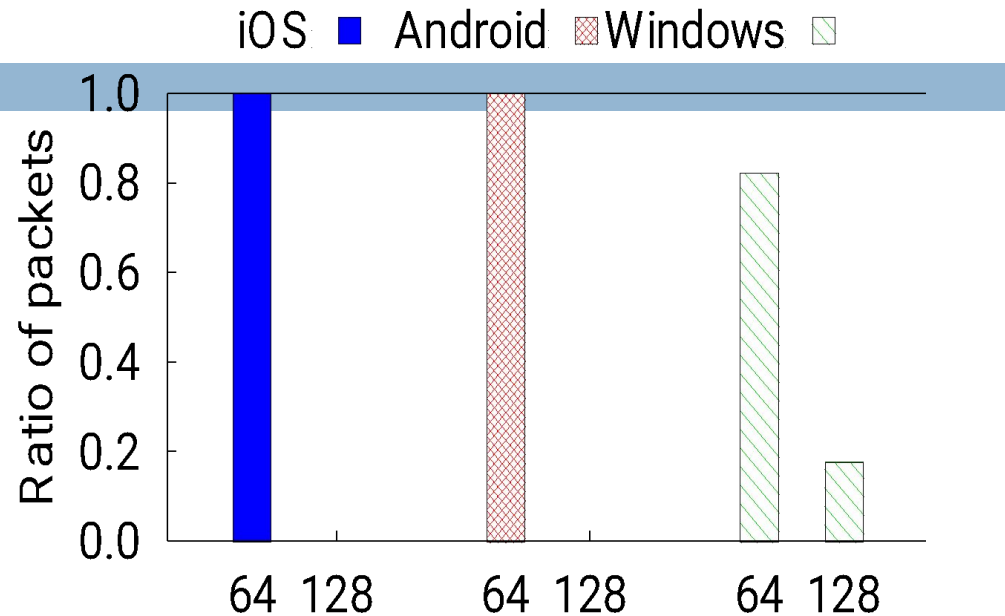
□ TCP Timestamp Option

Low ratio of TCP TS option suggests Windows.



Features

- IP Time-To-Live
- TCP Window Size Scale Option
- Boot time estimation



Combining Features

- **No single feature** works in all scenarios
- **Naïve Bayes classifier**

Probability of
being OS_x

Probability of finding
feature f_i in OS_x 's traffic

Probability of finding
feature f_i in all traffic

Tethering Detection

- Apply the same technique for tethering detection.
- Features which identify mobile devices
 - IP Time-To-Live
 - TCP timestamp monotonicity
 - Clock frequency
 - Boot time estimation
 - **Multiple OSes**

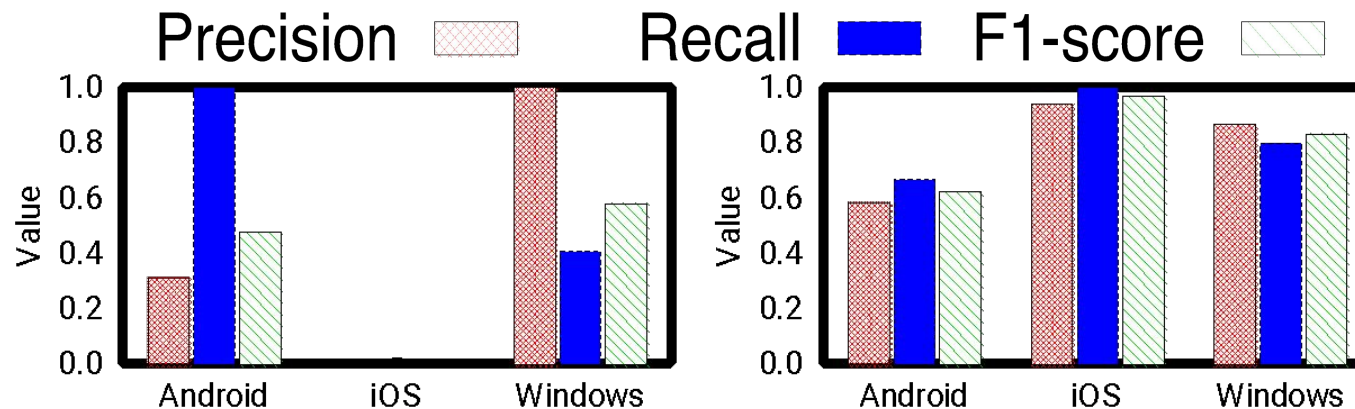
Evaluation – Single Feature

No single feature identifies all OSes accurately.

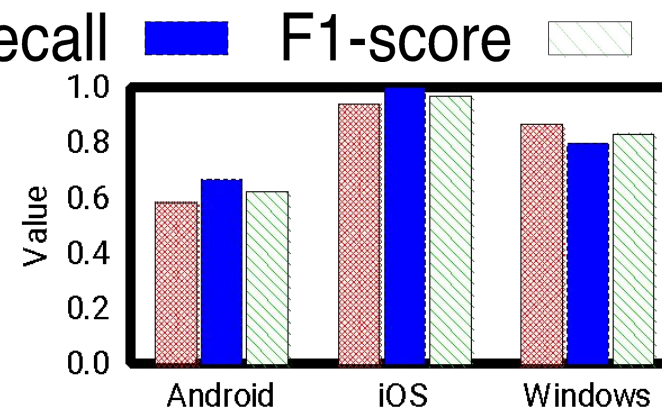
$$\textit{precision} = \frac{tp}{tp + fp}$$

$$\textit{recall} = \frac{tp}{tp + fn}$$

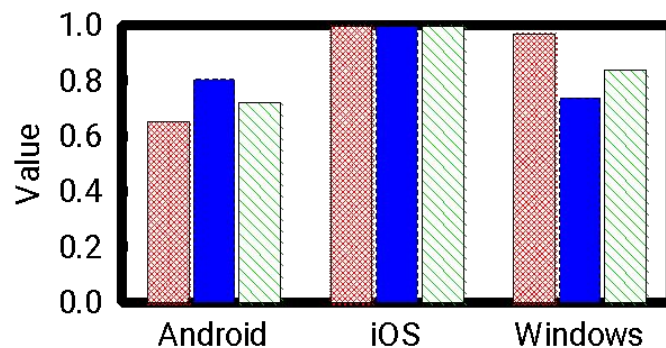
$$F1 = 2 \frac{\textit{prec} \times \textit{recall}}{\textit{prec} + \textit{recall}}$$



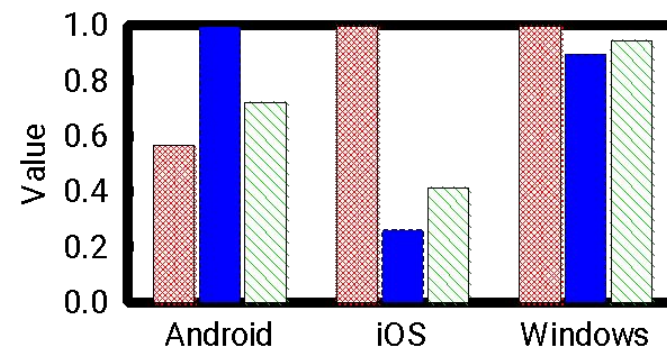
(a) TTL



(b) IP ID monotonicity



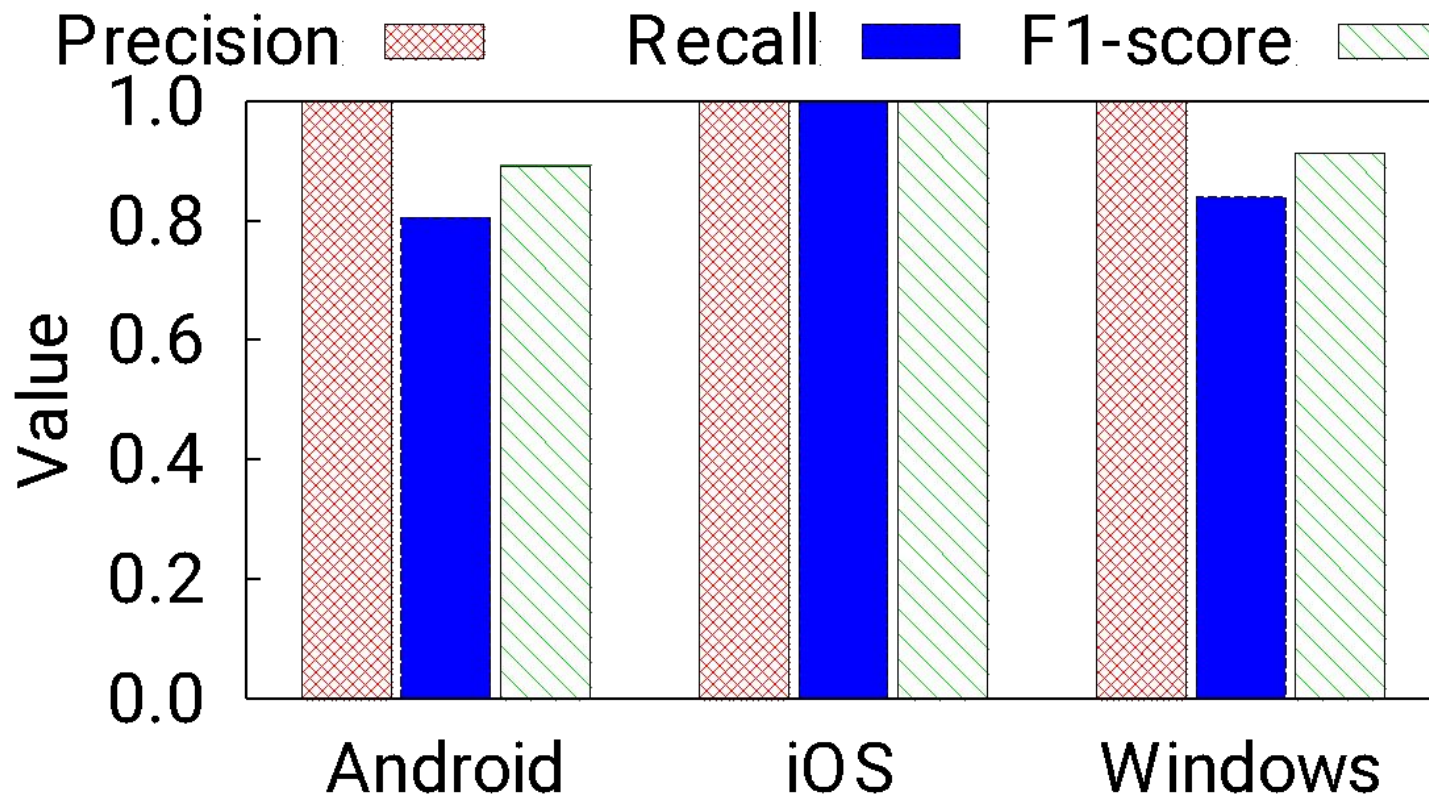
(c) TCP window scale



(d) Clock frequency stability

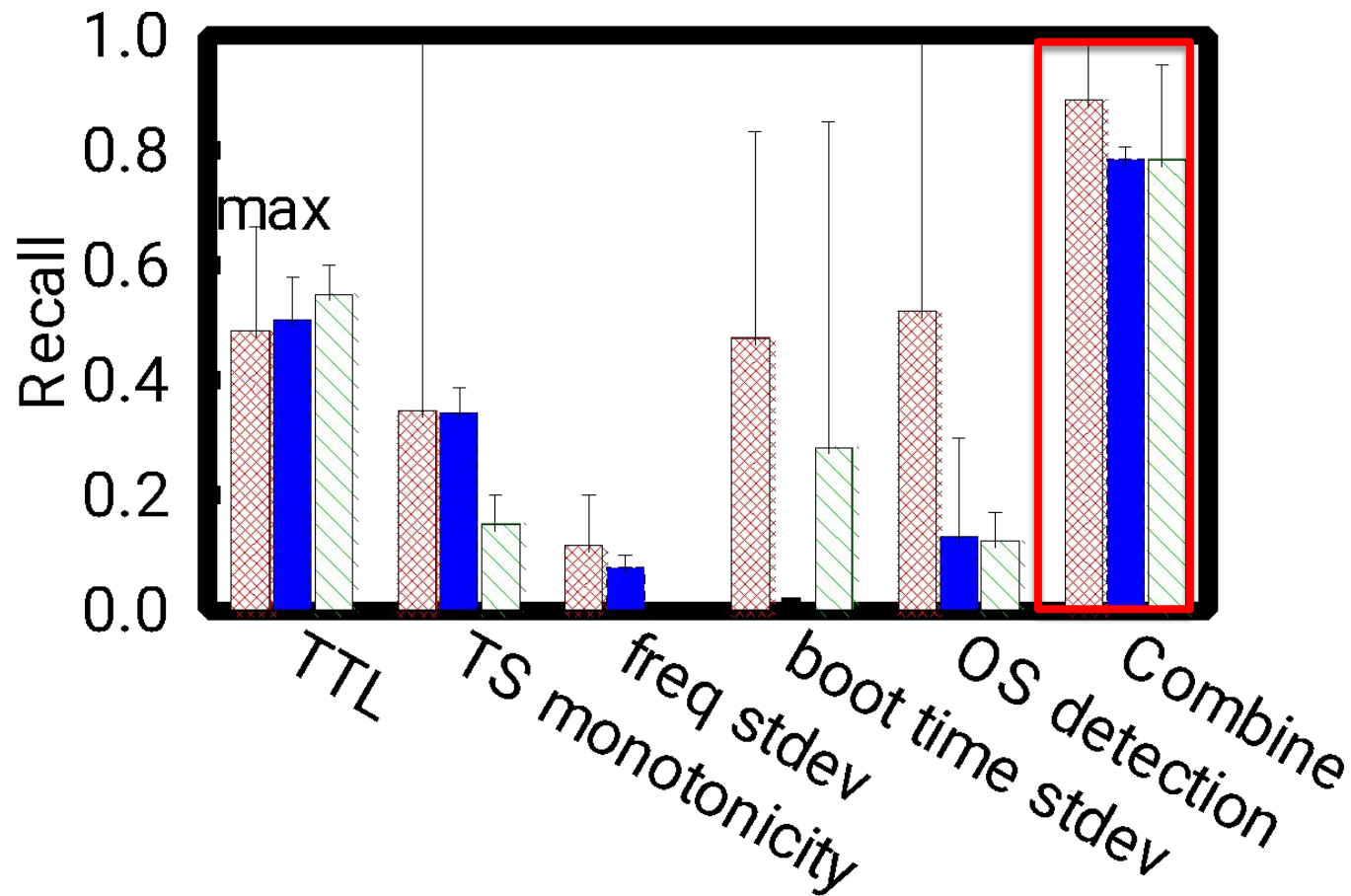
Evaluation – Combining Features

Combining all features yields the best result.



Evaluation – Tethering Detection

Combining all features also yields the best result in tethering detection.



Conclusion

- **Contributions**
 - Identify new features for **mobile** OS fingerprinting and tethering detection
 - Develop a probabilistic scheme that combines multiple features
- **Evaluate the individual and combined features**
 - Combining multiple features yields the best performance
 - OS fingerprinting: 100% precision, 80% recall
 - Tethering detection: 79%-89% recall when targeting 80% precision

Thank You!

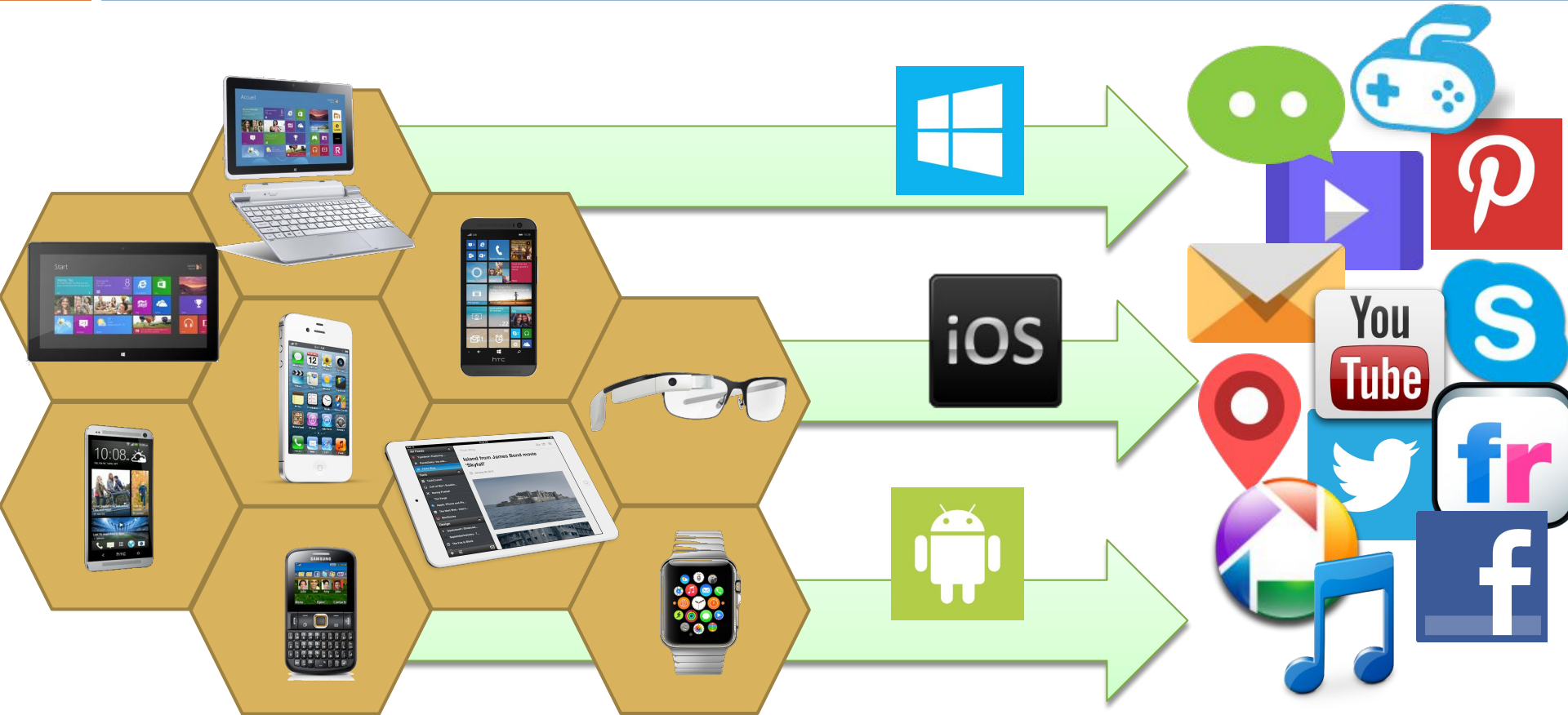
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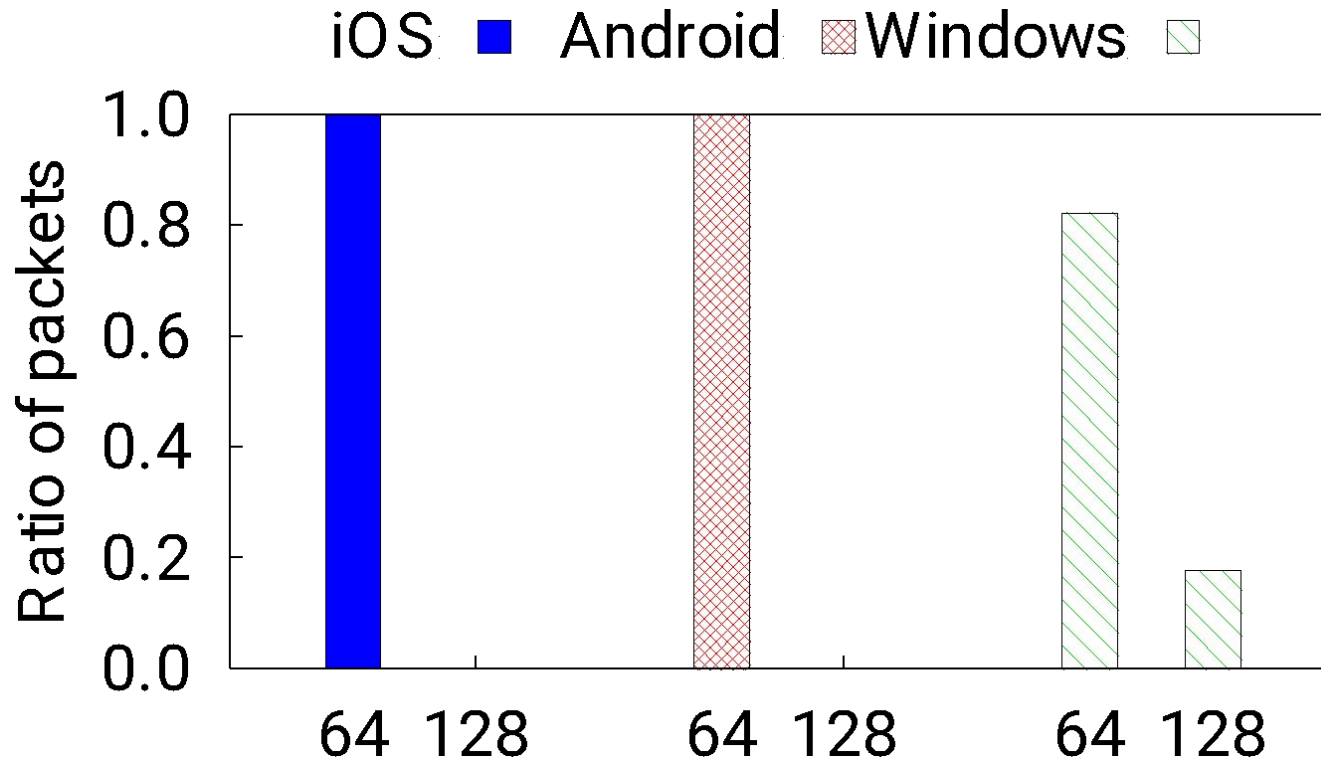
Backup Slides

Mobile OS Fingerprinting



Features

- **IP Time-To-Live (TTL)**
 - **Windows: 64 or 128**
 - **iOS and Android: 64**

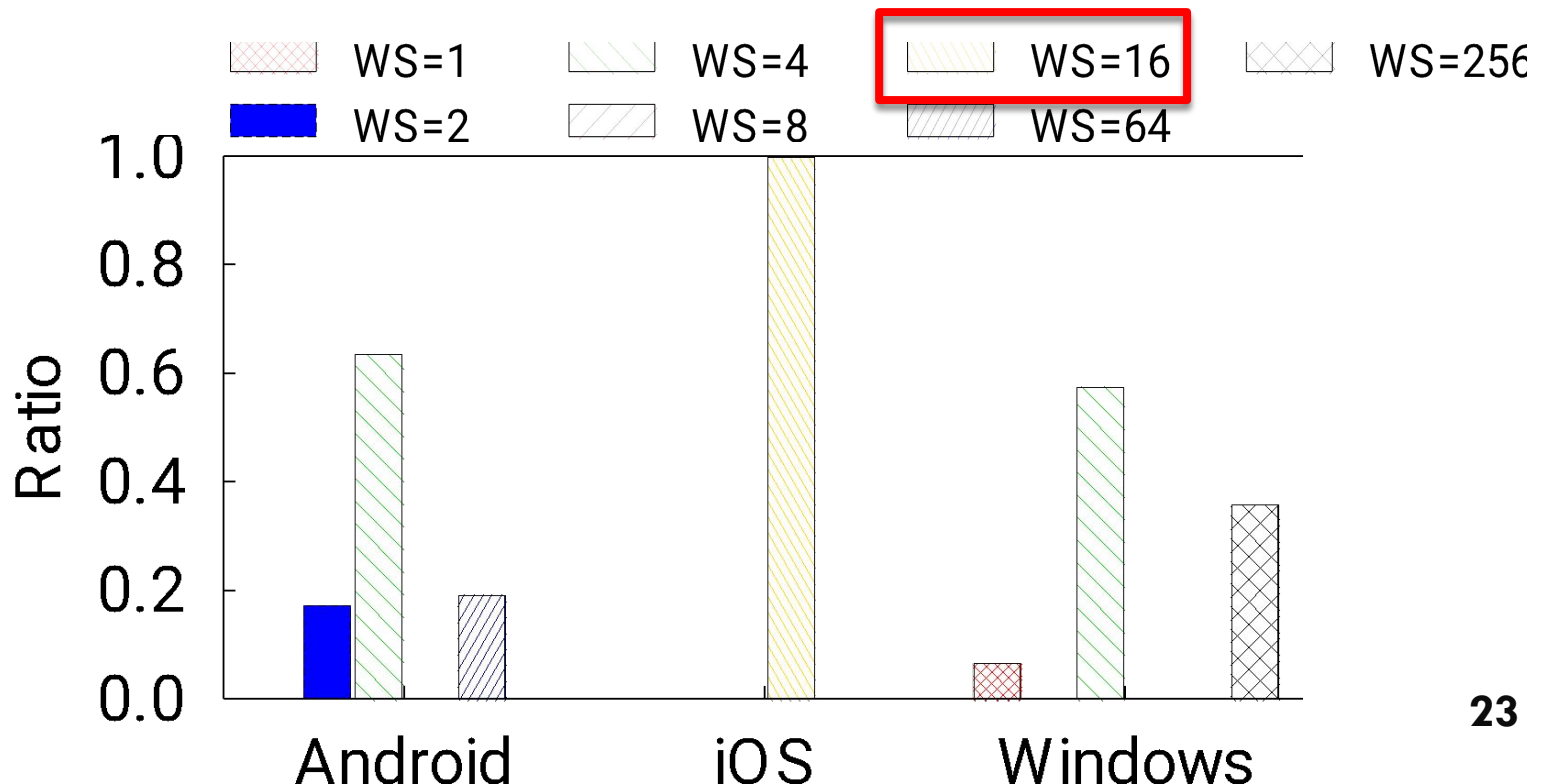


Features

□ TCP Window Size Scale Option

□ iOS: 16

□ Windows and Android: 2, 4, 64, or 256



Evaluation – Comparing Classifiers

Probability based classifier outperforms other classifiers by 5~21% in F1-score measurement.

