3G Meets the Internet: Understanding the Performance of Hierarchical Routing in 3G Networks

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Joint work with

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Outline

- Background
- Hierarchical routing vs. flat routing
- Hierarchical routing and replicated service
- Possible interaction with application layer
- Summary

Why do we care about 3G performance

User's expectation on 3G performance is higher than ever before

YouTube
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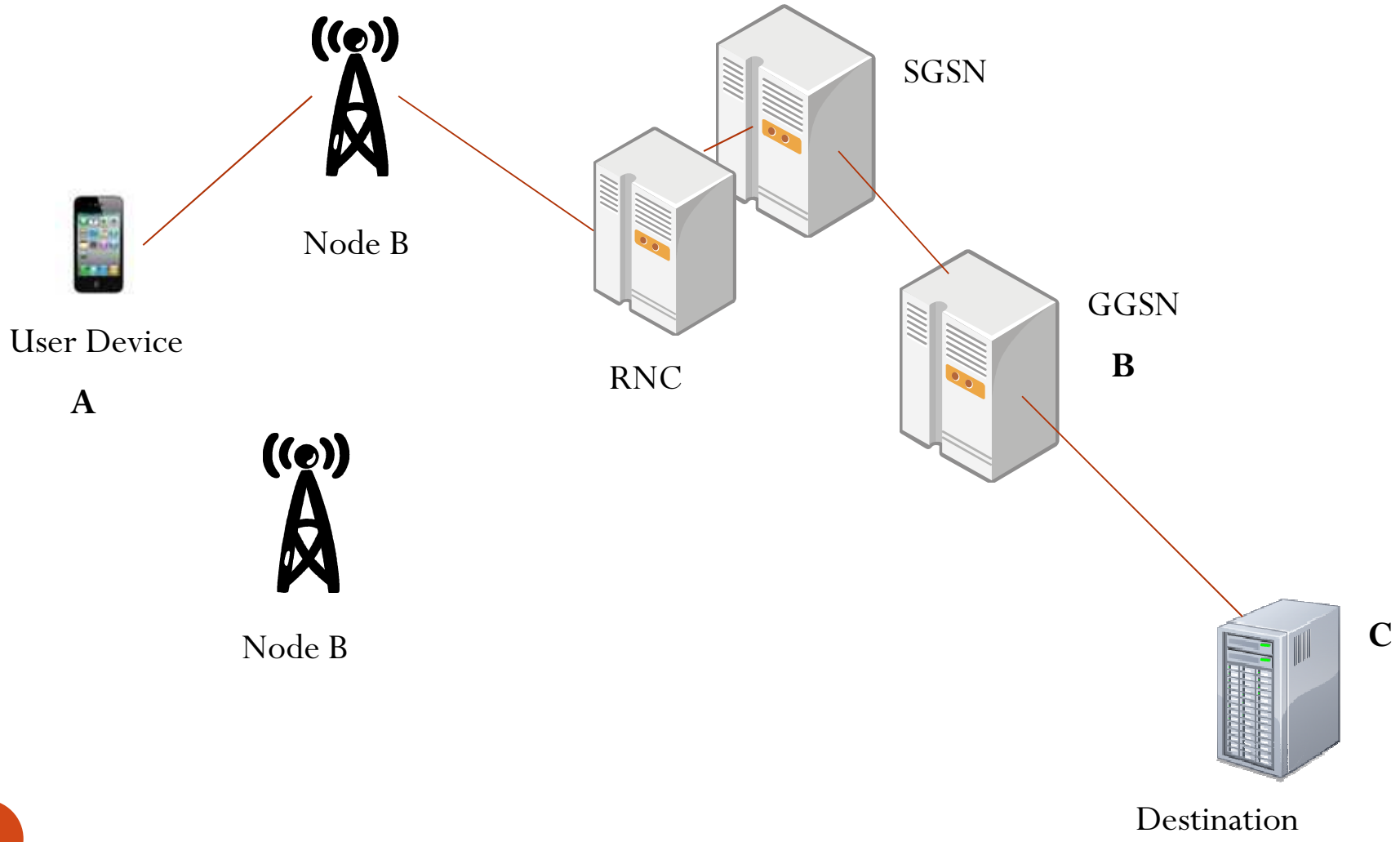
Simplified 3G Architecture



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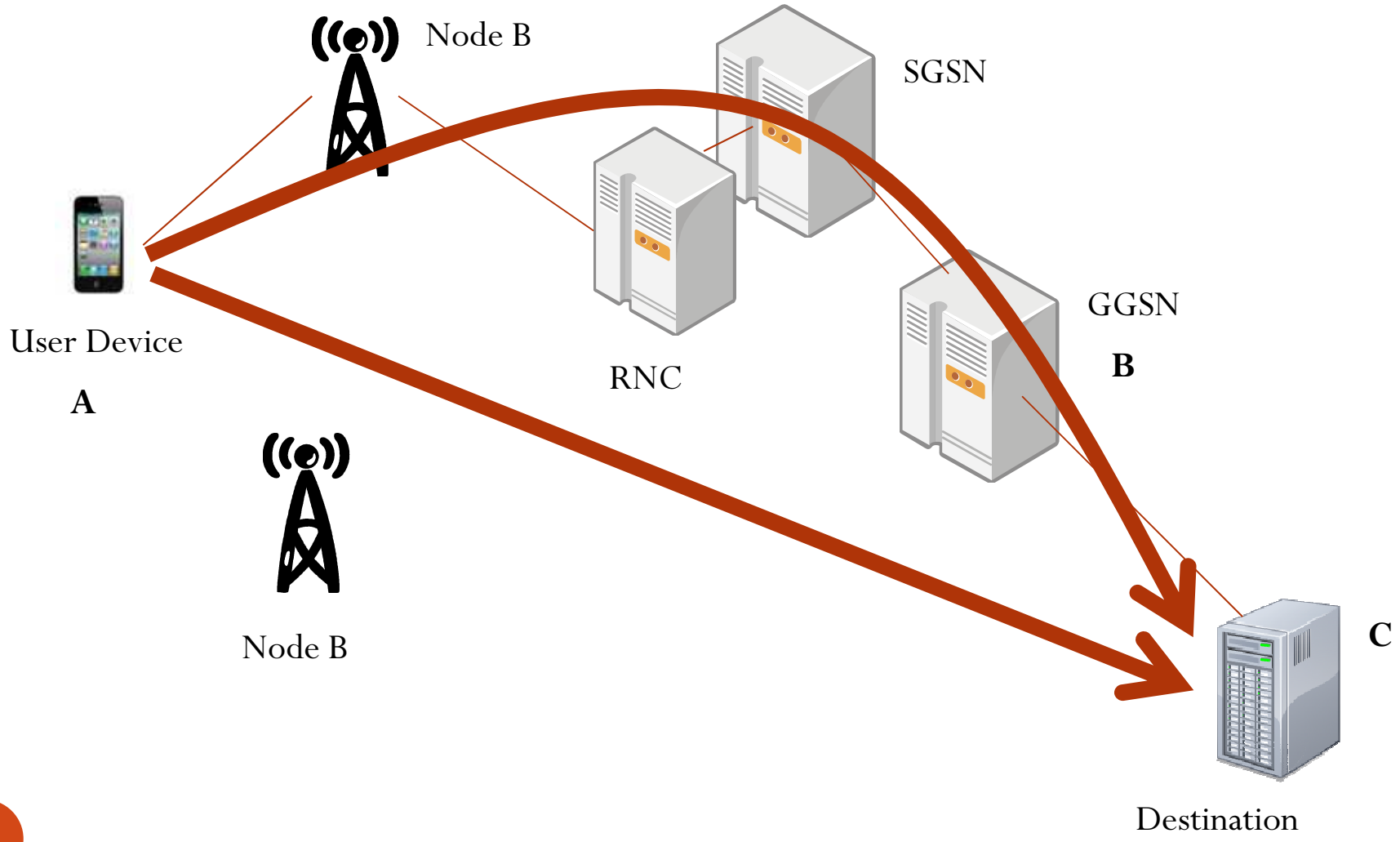
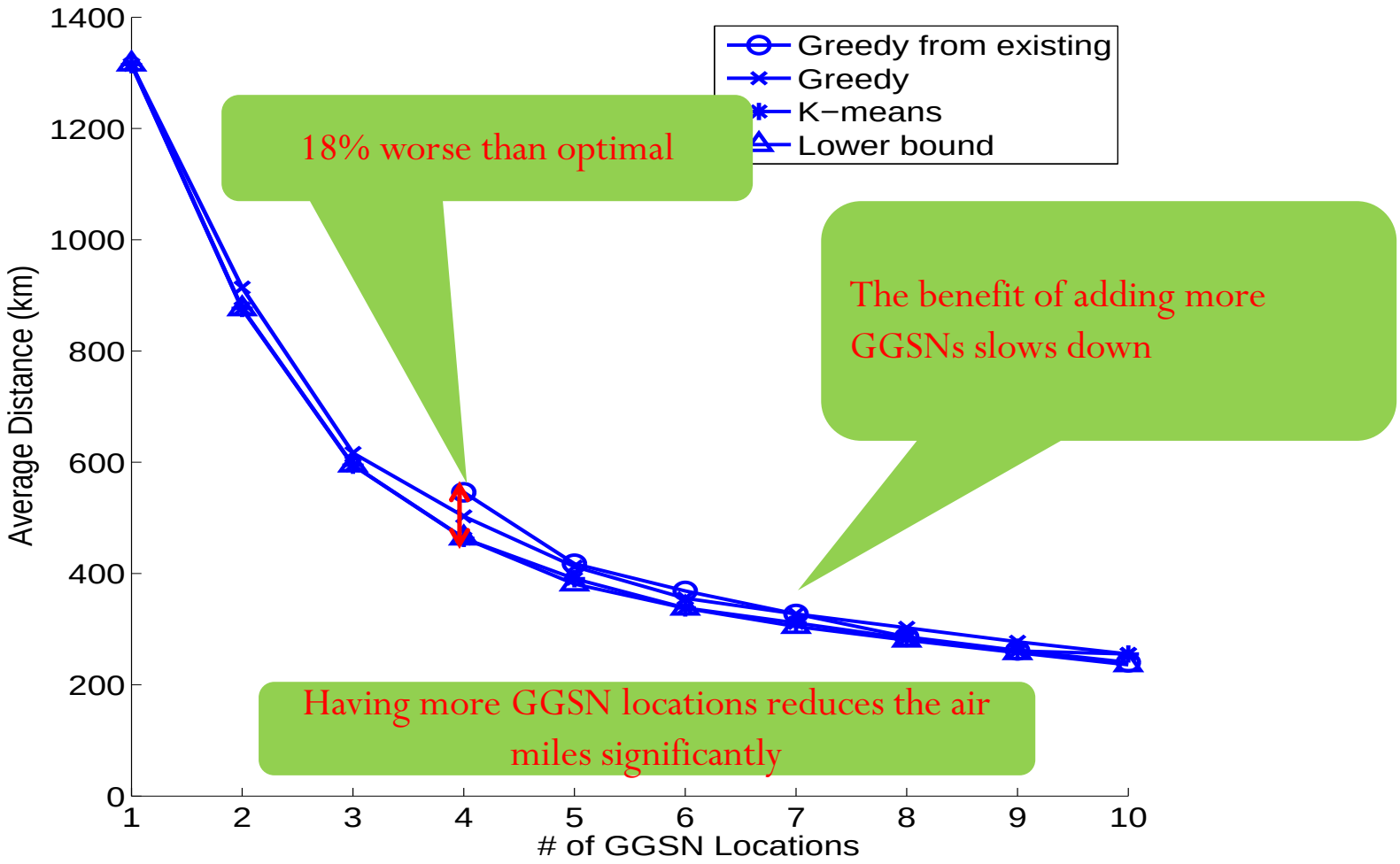
Hierarchical routing vs. flat routing



Air Mile to GGSN

- How long average packet travels (i.e., air mile)?
  - Metric: distance from RNC to SGSN to GGSN
  - Weighted average using traffic volume at RNC for a week
- How average air mile changes as number of GGSNs varies
  - More GGSNs make the network increasingly flat
  - Incremental (start from 4 most populated cities) vs. from-the-scratch
  - Use all RNCs as candidate locations
- Heuristics for placement
  - Greedy: iteratively choose the best location one by one
  - K-means: Clustering based on K initial points
    - We use the best of 10 runs with different random seeds

Placement Result



Number of GGSN **VS** Weighted average distance

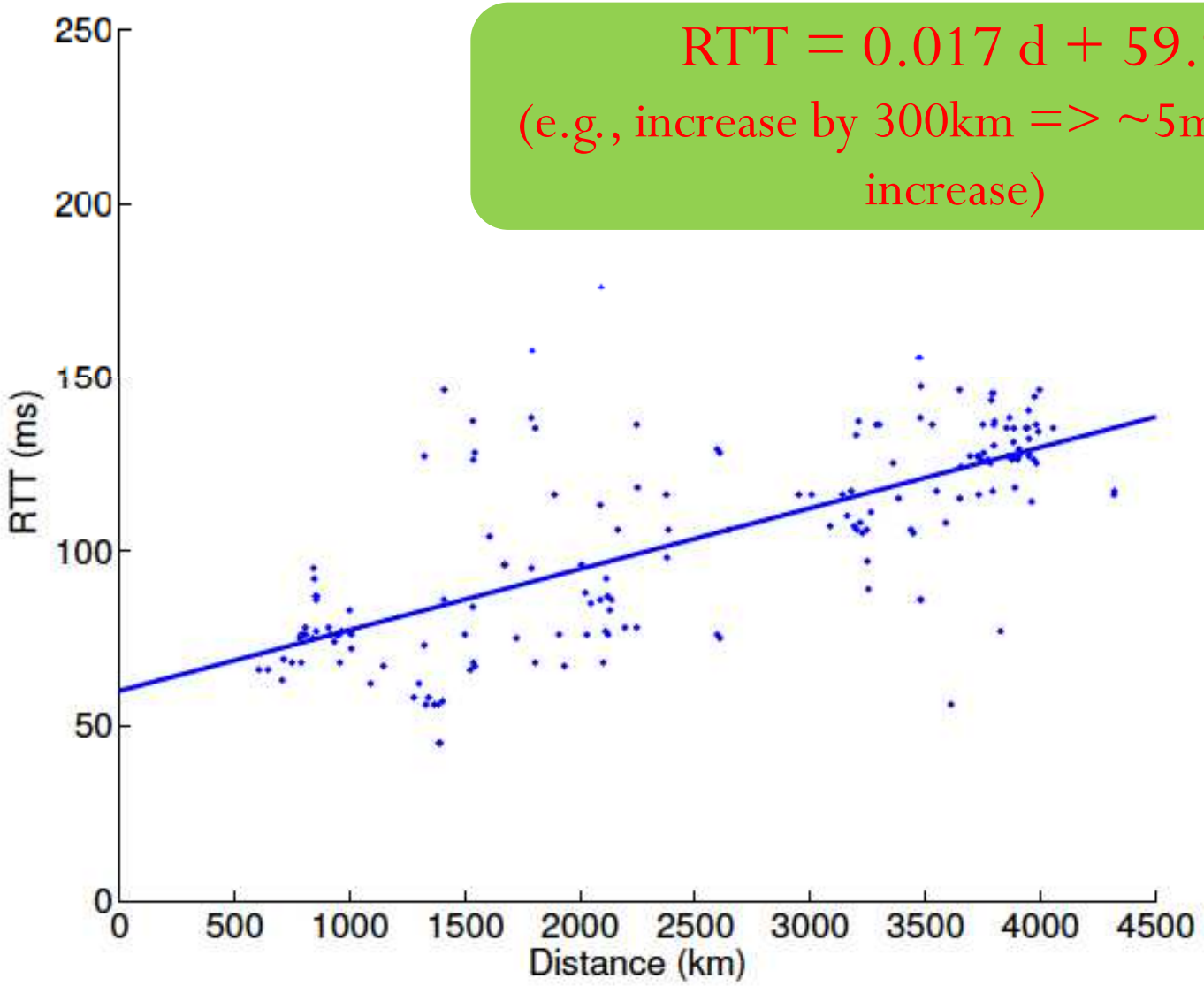
How does distance translate to delay?

- Curve fitting using periodic probe data
  - Probe devices are at about 250 different locations across the nation
    - ~70 3G devices
    - ~180 HSPA devices
  - One or two ping measurements per hour
    - We use the min for each (probe, server) pair for a day
  - Consider detour routing through GGSN when calculating distance
    - Probe-> SGSN -> GGSN -> Server (external or internal)

Distance vs. RTT (HSPA)

RTT = 0.017 d + 59.9

(e.g., increase by 300km => ~5ms latency increase)



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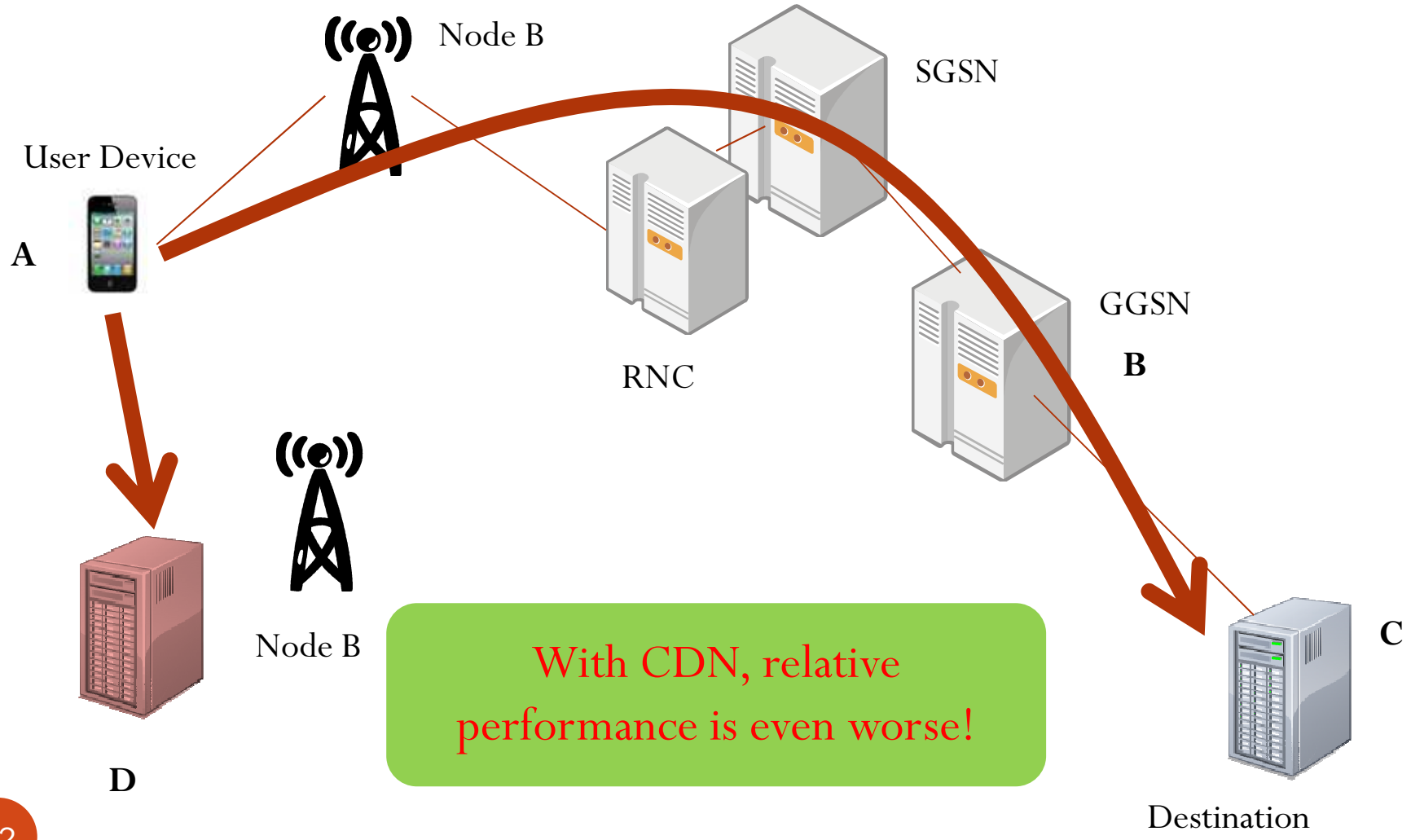
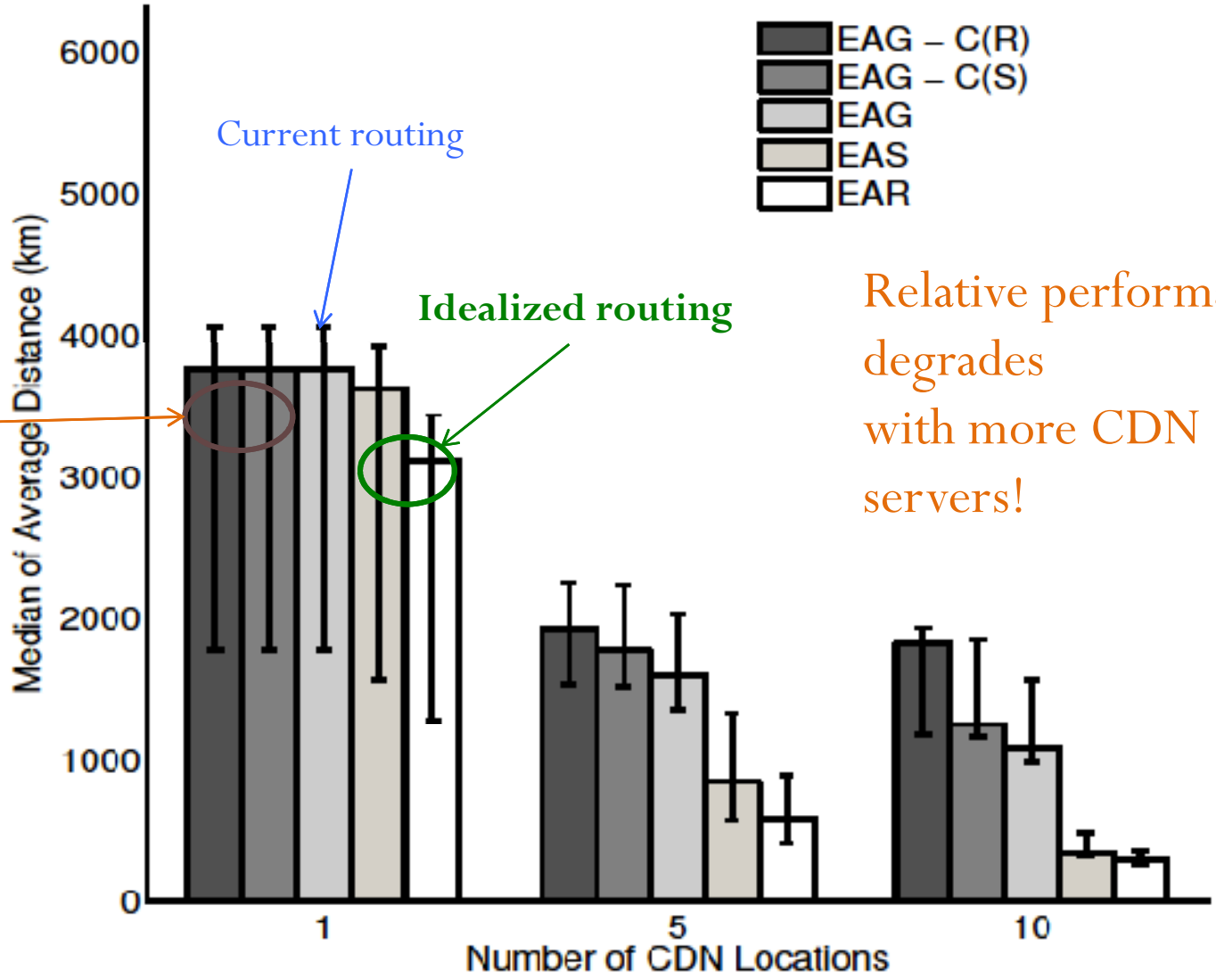
Hierarchical routing and replicated service



Hierarchical routing and replicated service

- Air mile to CDN server (weighted average)
  - EAG (Exit-at-GGSN): Current routing
    - RNC – SGSN – GGSN – CDN server
  - EAS, EAR (Exit at SGSN/RNC): idealized routing
    - RNC – SGSN – CDN or RNC – CDN
  - CDN server selection
    - Normal: closest to exit point
    - DNS caching can cause suboptimal selection (discussed later)
- Location information
  - RNC (hundreds of different locations), SGSN (tens of different locations), GGSN (tens of different locations)
  - Location of CDN servers (tens of different locations)

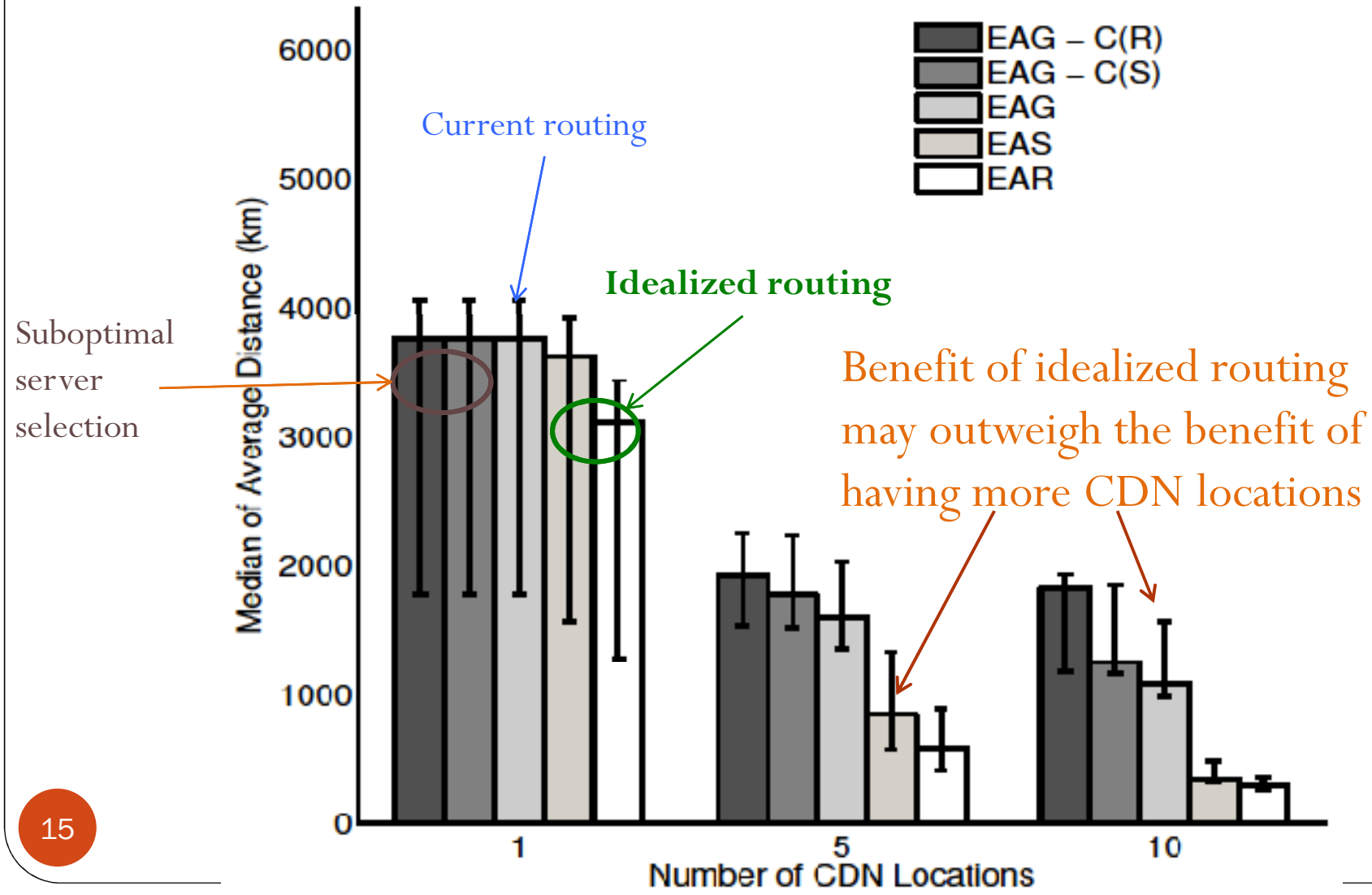
Air Mile vs. # CDN Locations



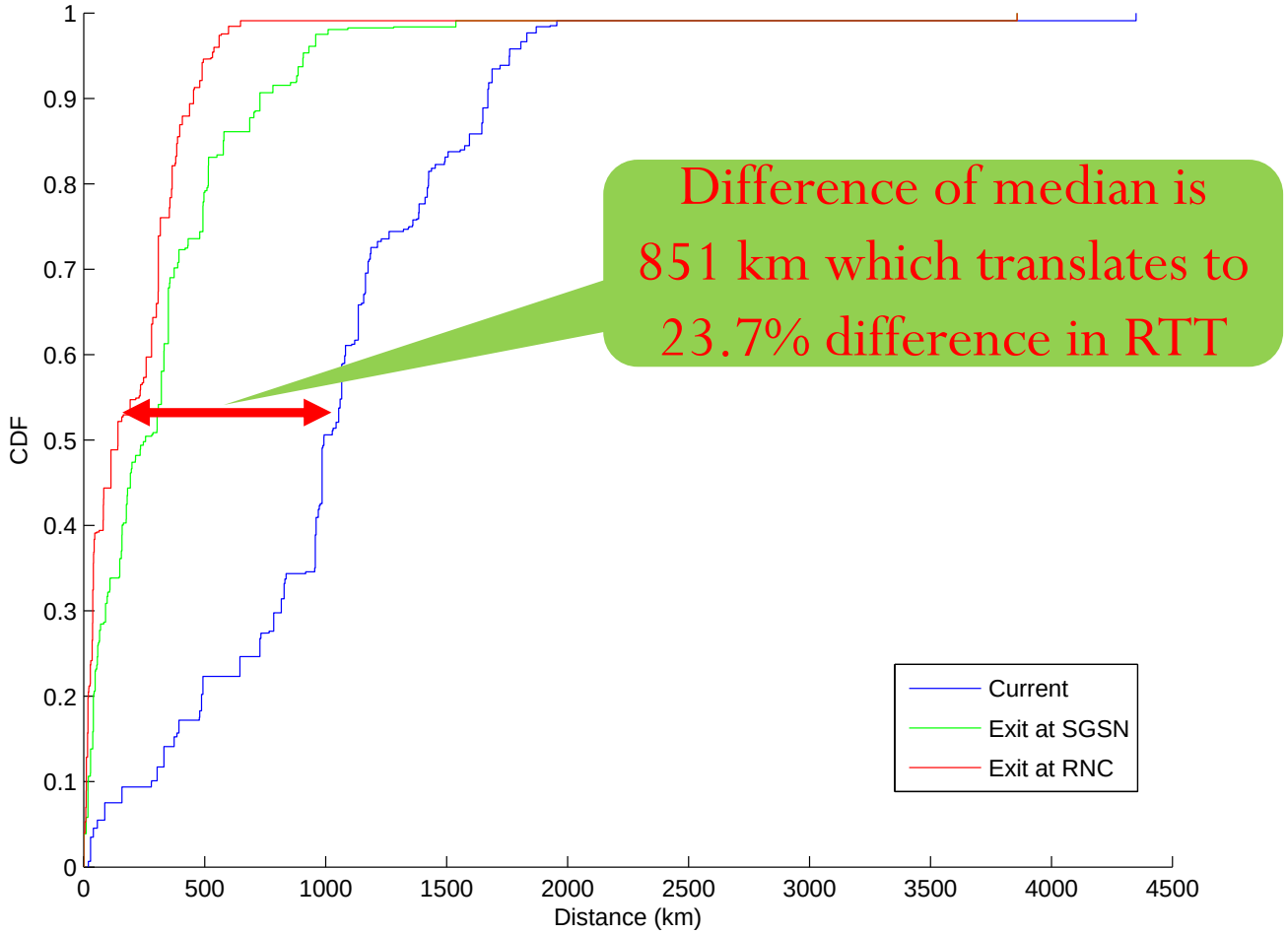
Suboptimal server selection

Relative performance degrades with more CDN servers!

Air Mile vs. # CDN Locations



Distance Distribution (tens of CDN Locations)



CDF of Distance

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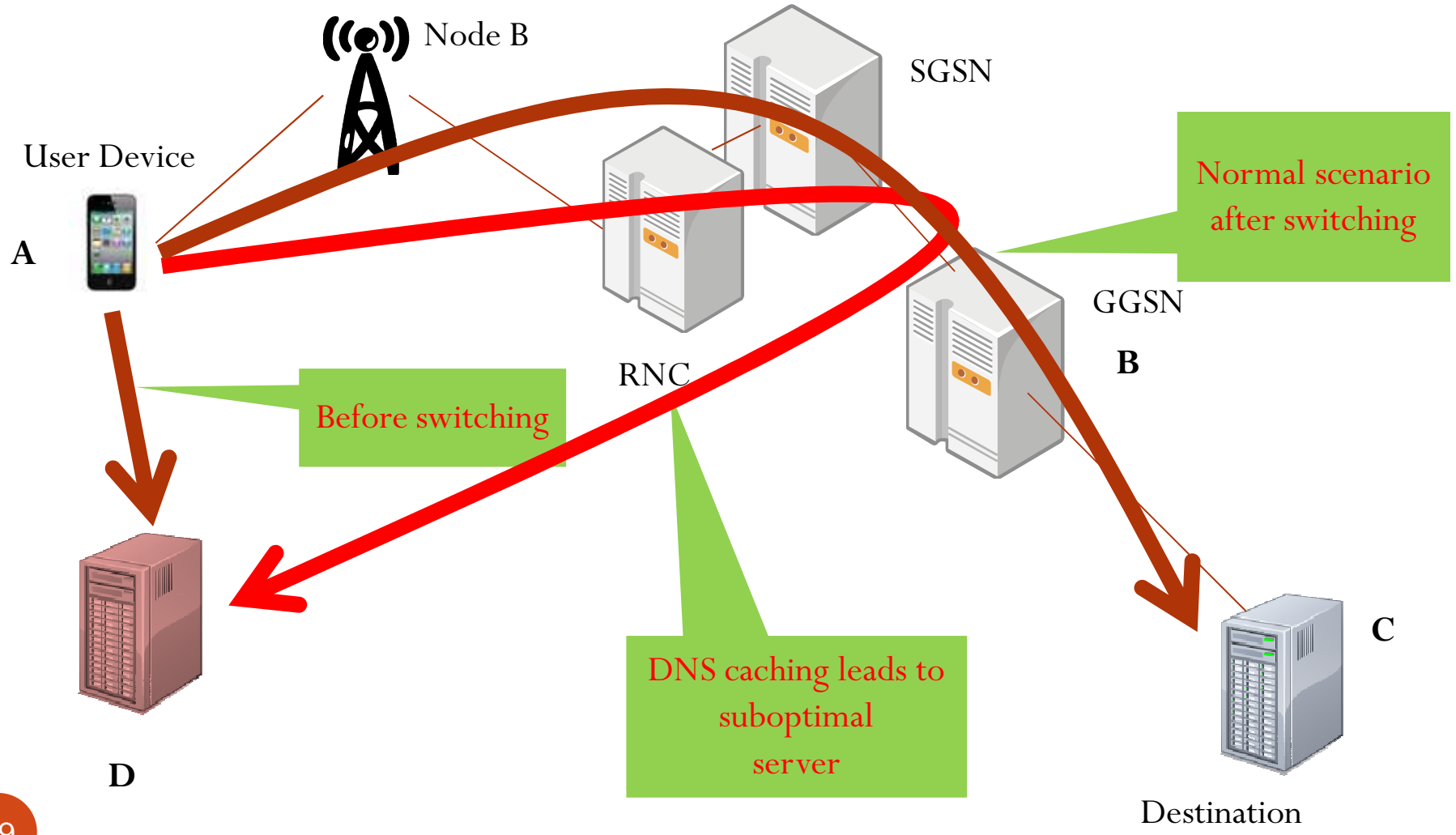
Interaction with DNS Caching

- Most CDNs use DNS to direct users to different servers
  - Browsers manage their own DNS cache
    - May not follow TTL set by DNS server

Browser	Timeout value (min)	Market share (%)
IE	30	60.74
Safari	5	5.09
Firefox	1	22.91

- User mobility may cause switching between WiFi and 3G interfaces
  - UE may use cached DNS entry and continue to go to old, suboptimal server

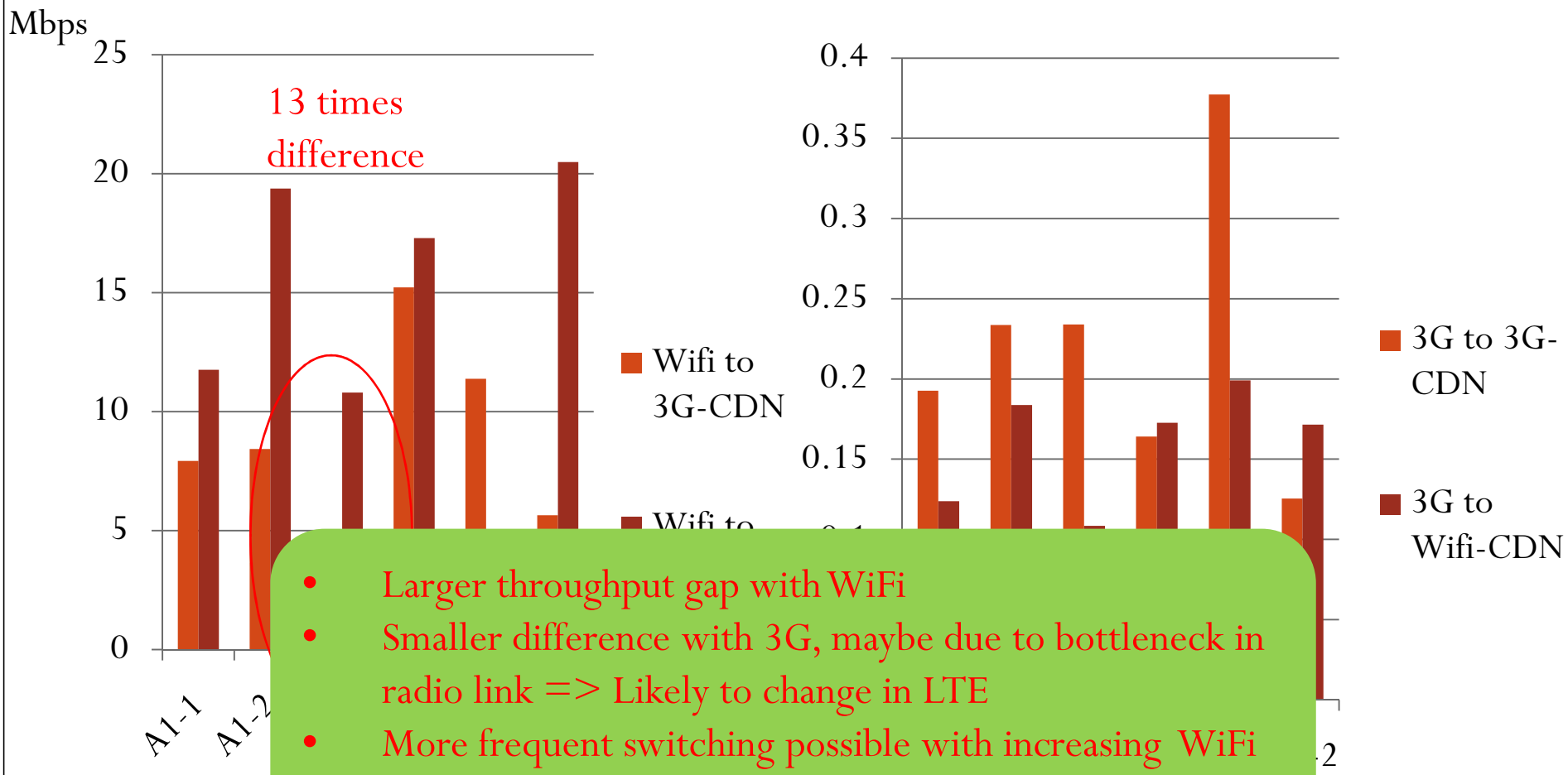
Switching from WiFi to 3G



Measurement Setup

- Measurement done on laptop PC with wifi card and USB 3G card.
- Browser: Internet Explorer
- Sites: Akamai customers
  - Manually switch between WiFi and 3G to emulate mobility
  - Measure the download throughput of video (*several minutes long*)
  - Four scenarios
    - On WiFi, using WiFi CDN server (returned by WiFI DNS server)
    - On WiFi, using 3G CDN server (returned by 3G DNS server)
    - On 3G, using WiFi CDN server
    - On 3G, using 3G CDN server

Measurement: Akamai Customers from NJ



- Larger throughput gap with WiFi
- Smaller difference with 3G, maybe due to bottleneck in radio link => Likely to change in LTE
- More frequent switching possible with increasing WiFi hotspots

Summary

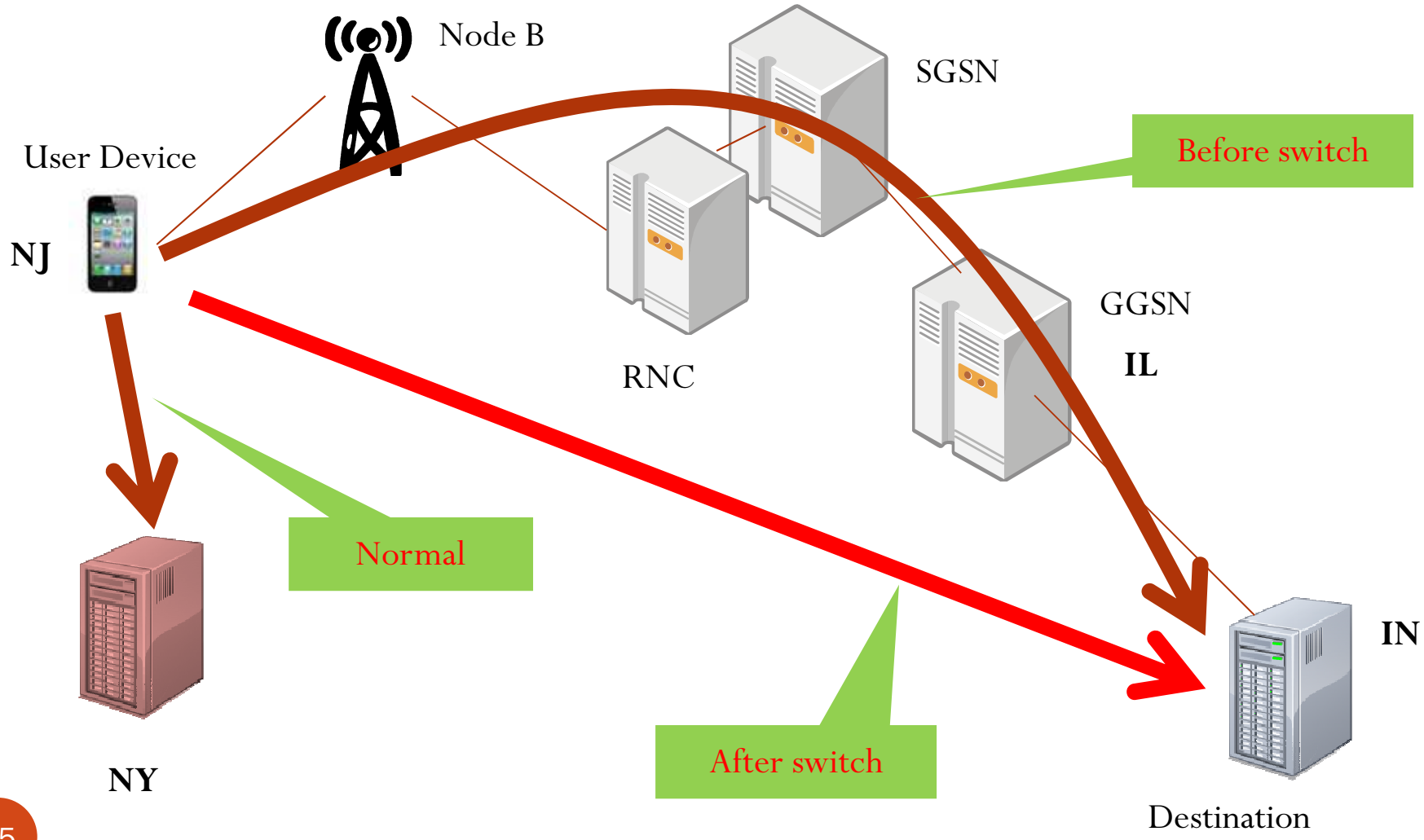
- Compared between idealized routing and current detour routing in 3G architecture
  - Flat routing reduces air mile significantly but the difference in end-to-end delay is only modest
  - Relative performance gap grows with replicated service
  - Interaction between routing change and DNS caching can cause up to an order of magnitude throughput degradation
- Our findings not only apply to current 3G networks
  - The difference in end-to-end delay can grow as wireless technology improves further
  - The use of aggregation points still applies to recent cellular architectures such as EPC

Q&A

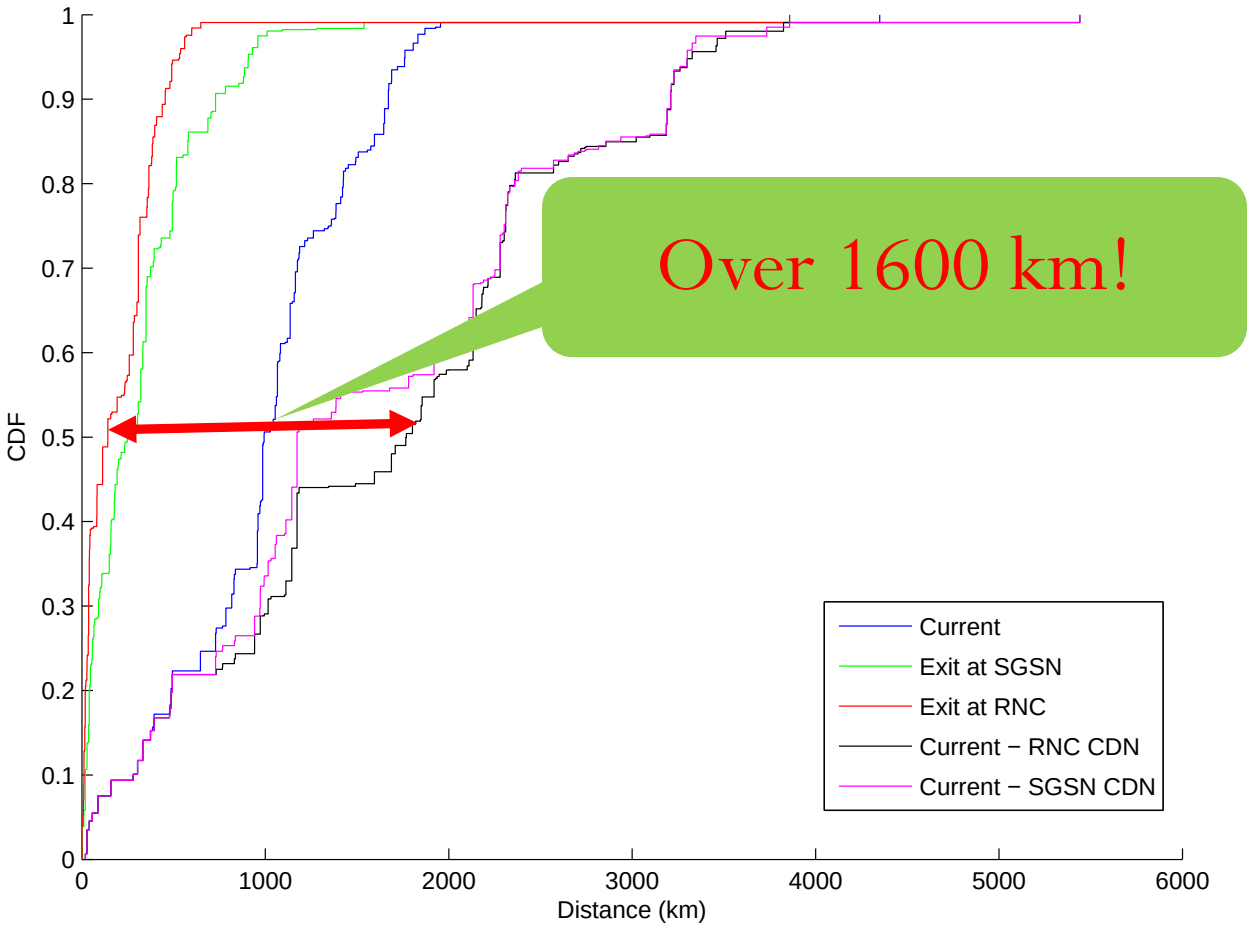
Thanks!

Backup Slides

Switch from 3G to wifi

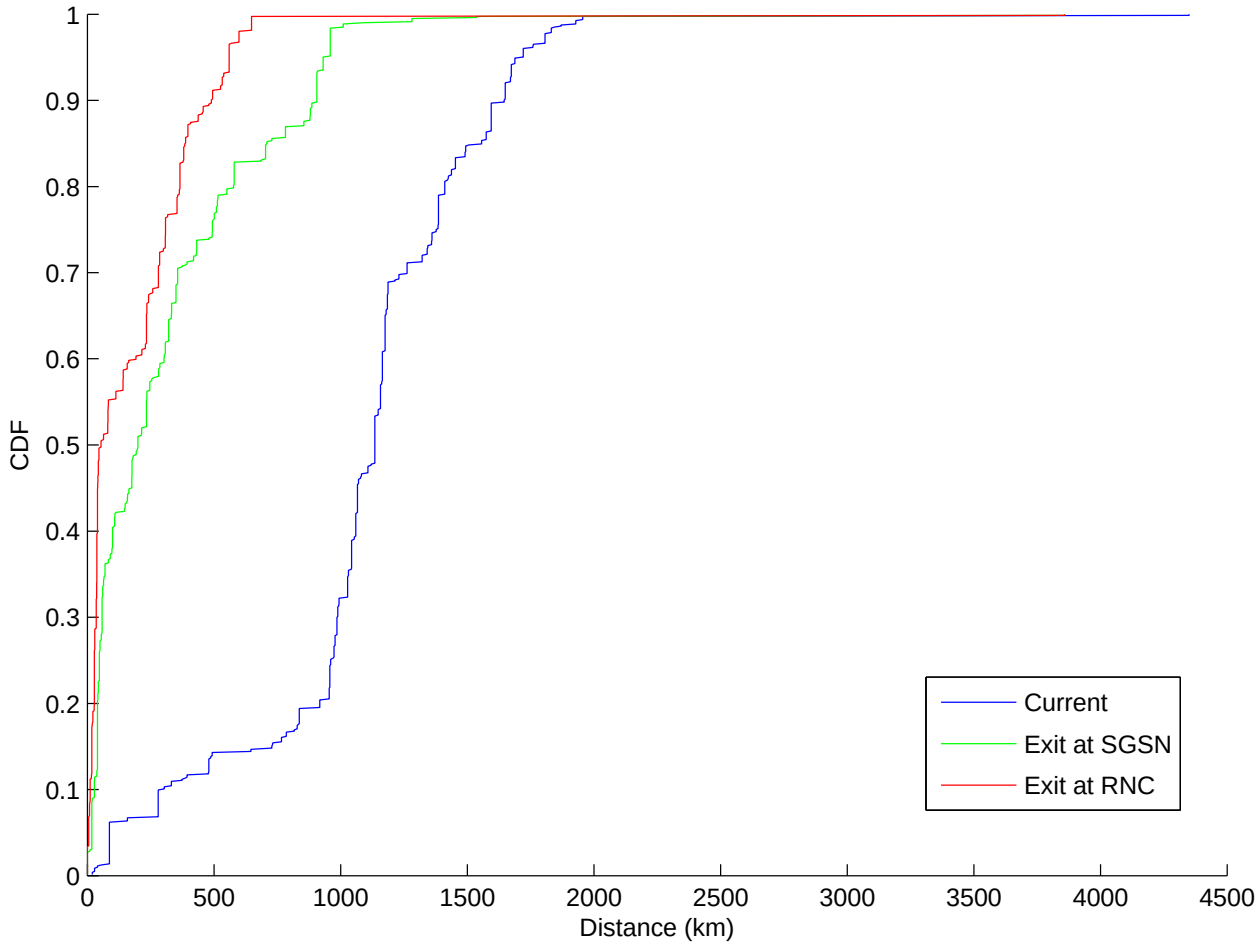


Considering routing change



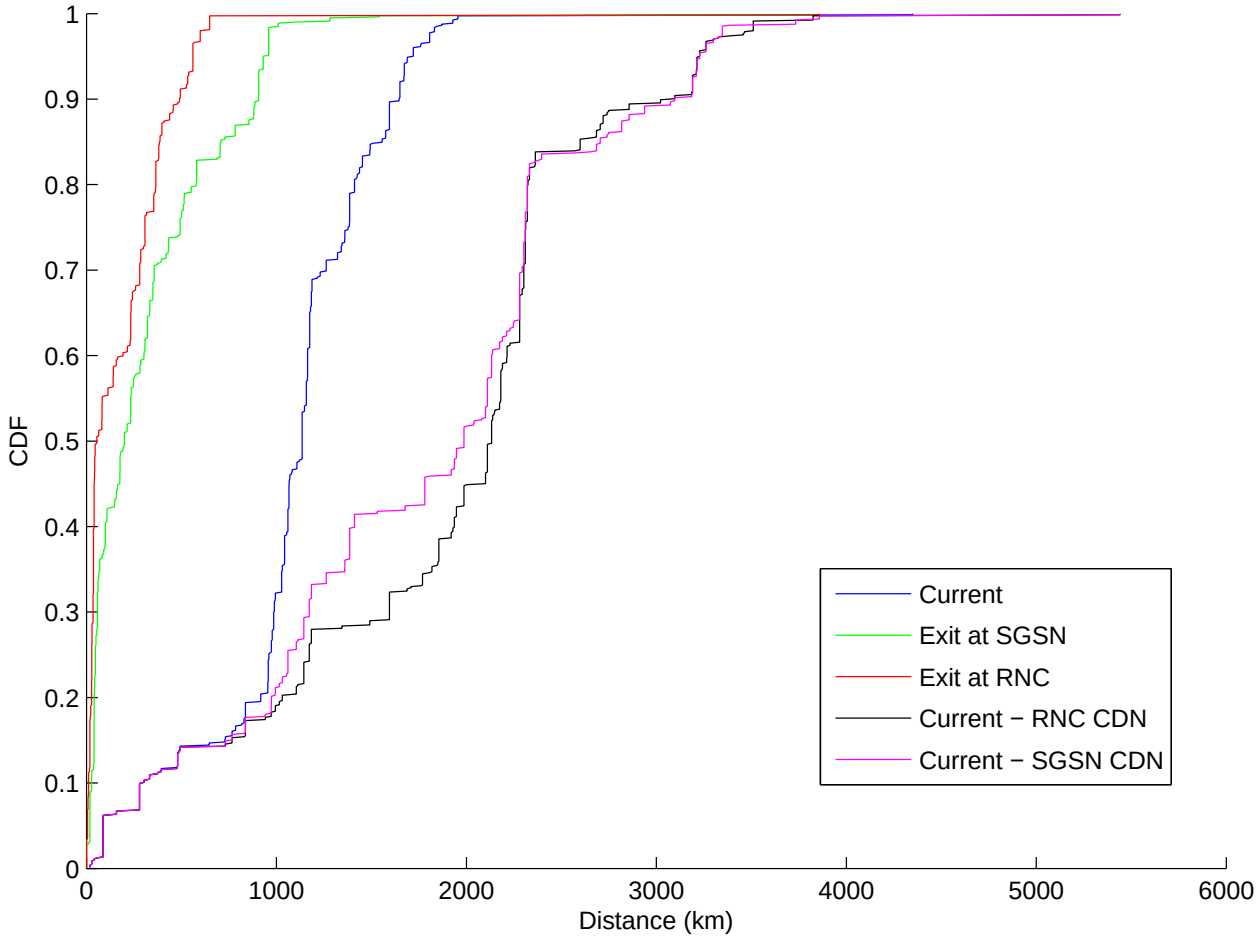
CDF of Distance

Cost of triangular routing



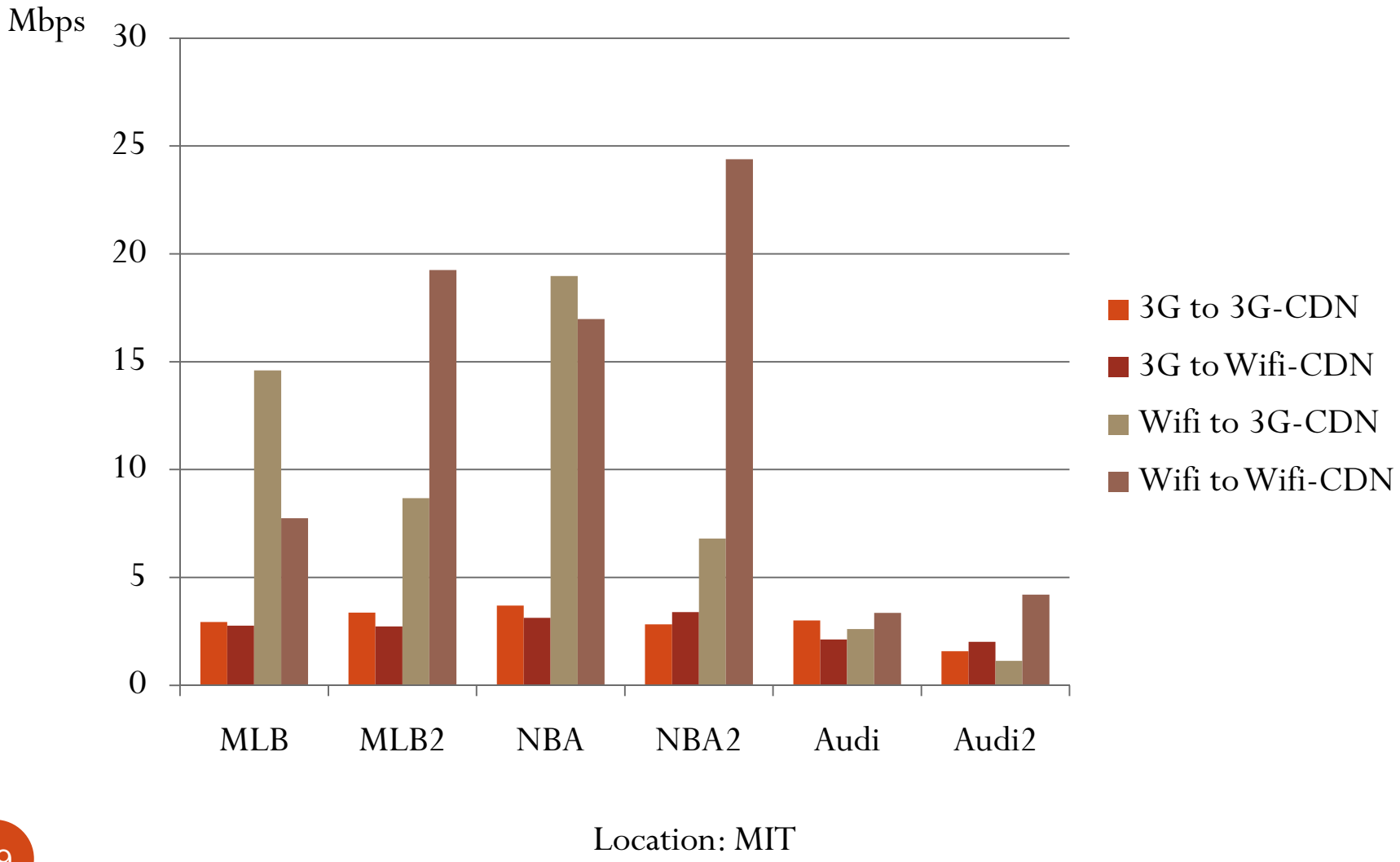
CDF of distance based on RNCs

Considering routing change…

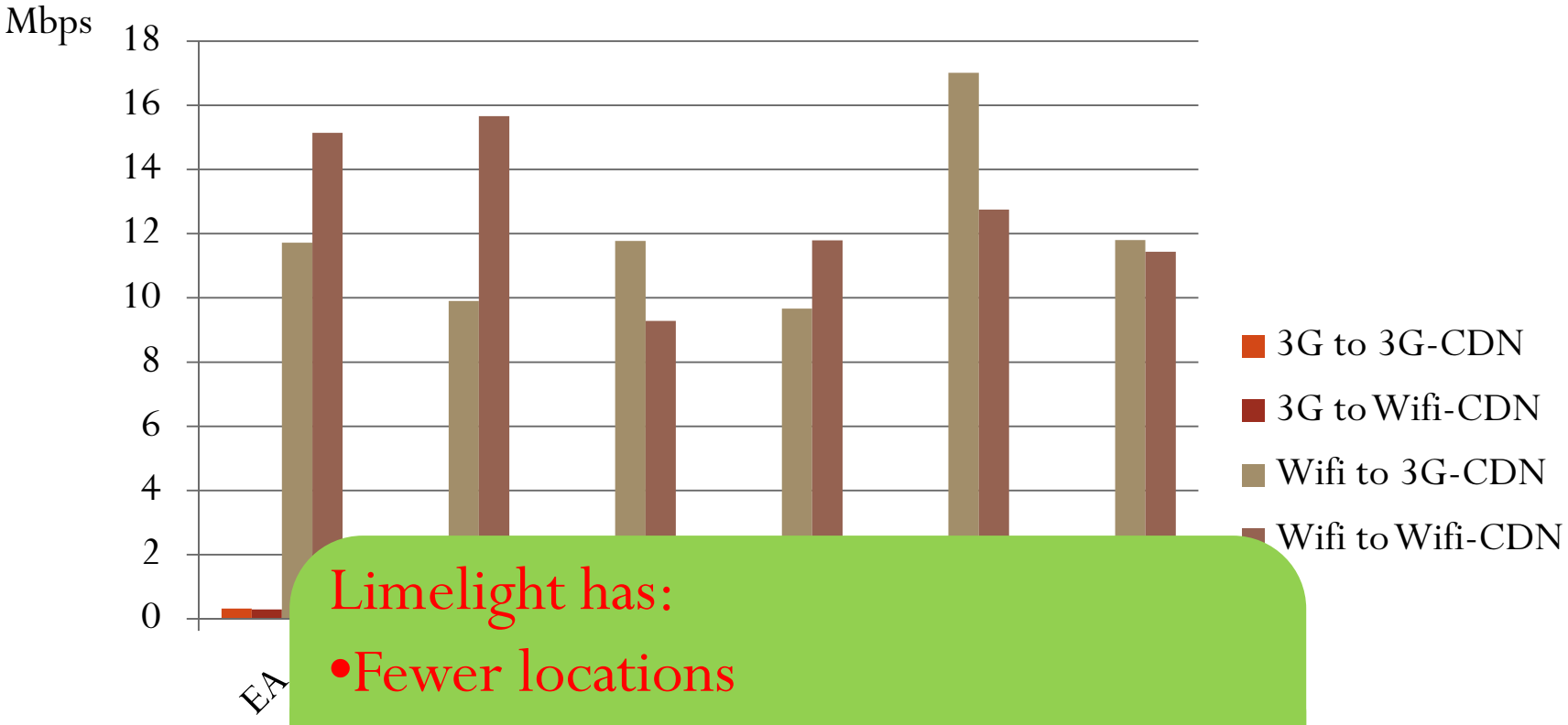


CDF of distance based on RNCs

Measurement on Akamai customers from MA



Measurement on Limelight customers from NJ



Limelight has:

- Fewer locations
- Better connectivity to last mile providers via a global fiber-optic network

Summary of measurement result

- Inefficiency is more obvious when switch from 3G to Wifi
  - For 3G the air interface is the dominant part
- Inefficiency is less obvious when there are fewer locations to choose from
  - Akamai VS Limelight
- Can become bigger issue in the future
  - Advances in wireless technology
  - Vertical handoff

Measurement on Akamai customers from NJ – RTT