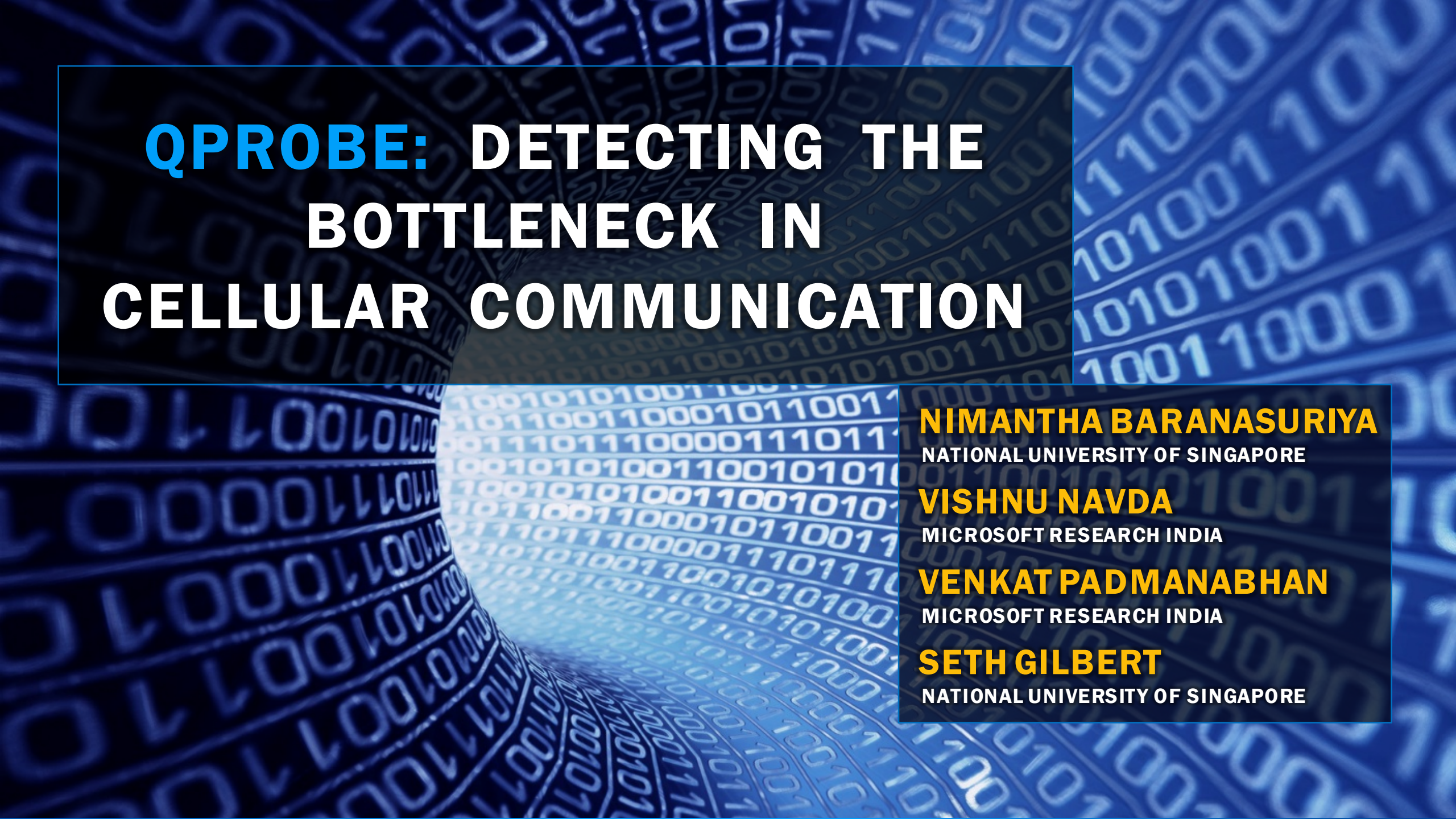

QPROBE: DETECTING THE BOTTLENECK IN CELLULAR COMMUNICATION

NIMANTHA BARANASURIYA
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VISHNU NAVDA
MICROSOFT RESEARCH INDIA

VENKAT PADMANABHAN
MICROSOFT RESEARCH INDIA

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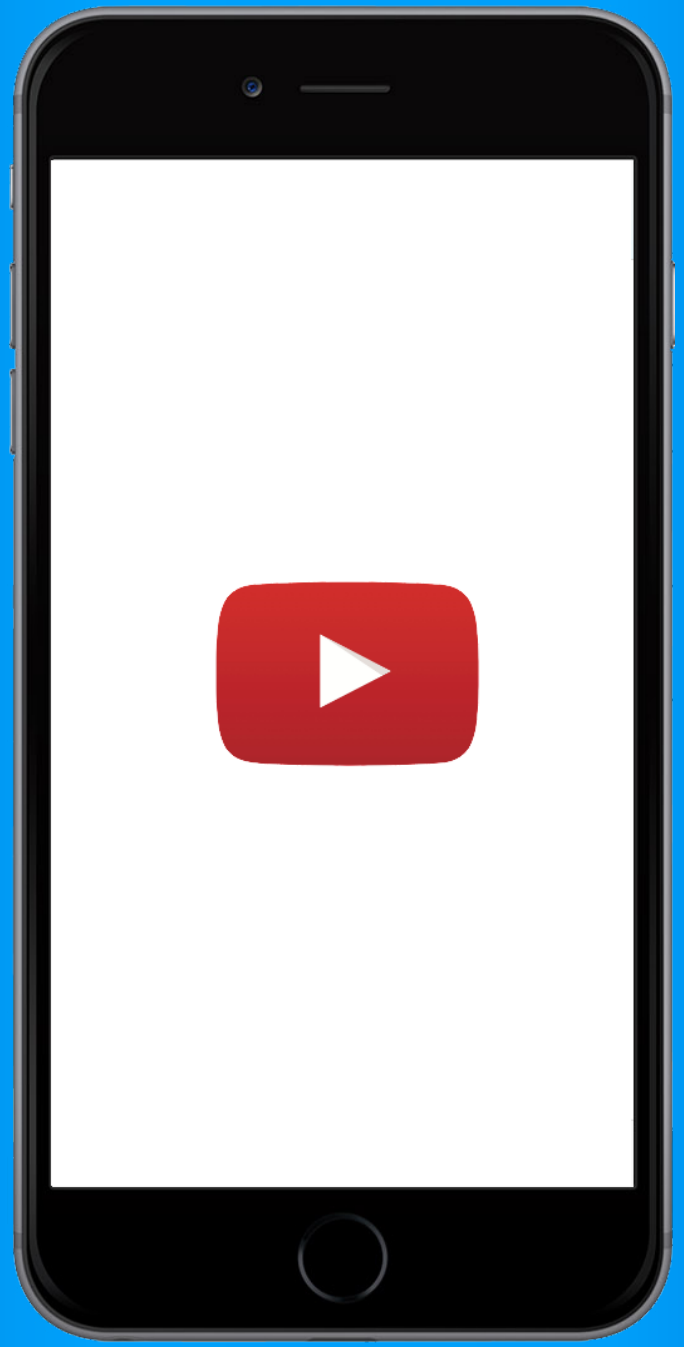
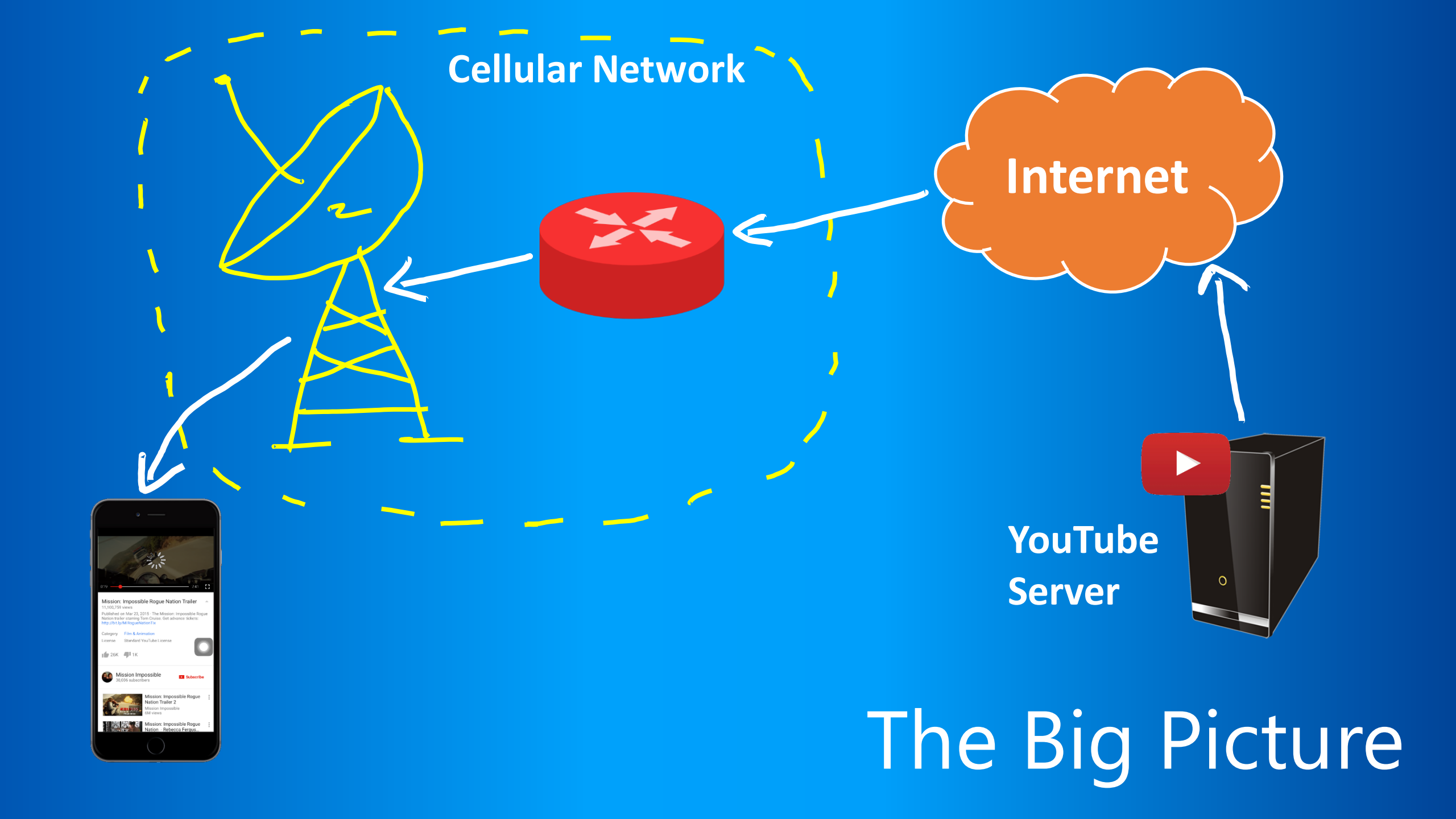
NATIONAL UNIVERSITY OF SINGAPORE

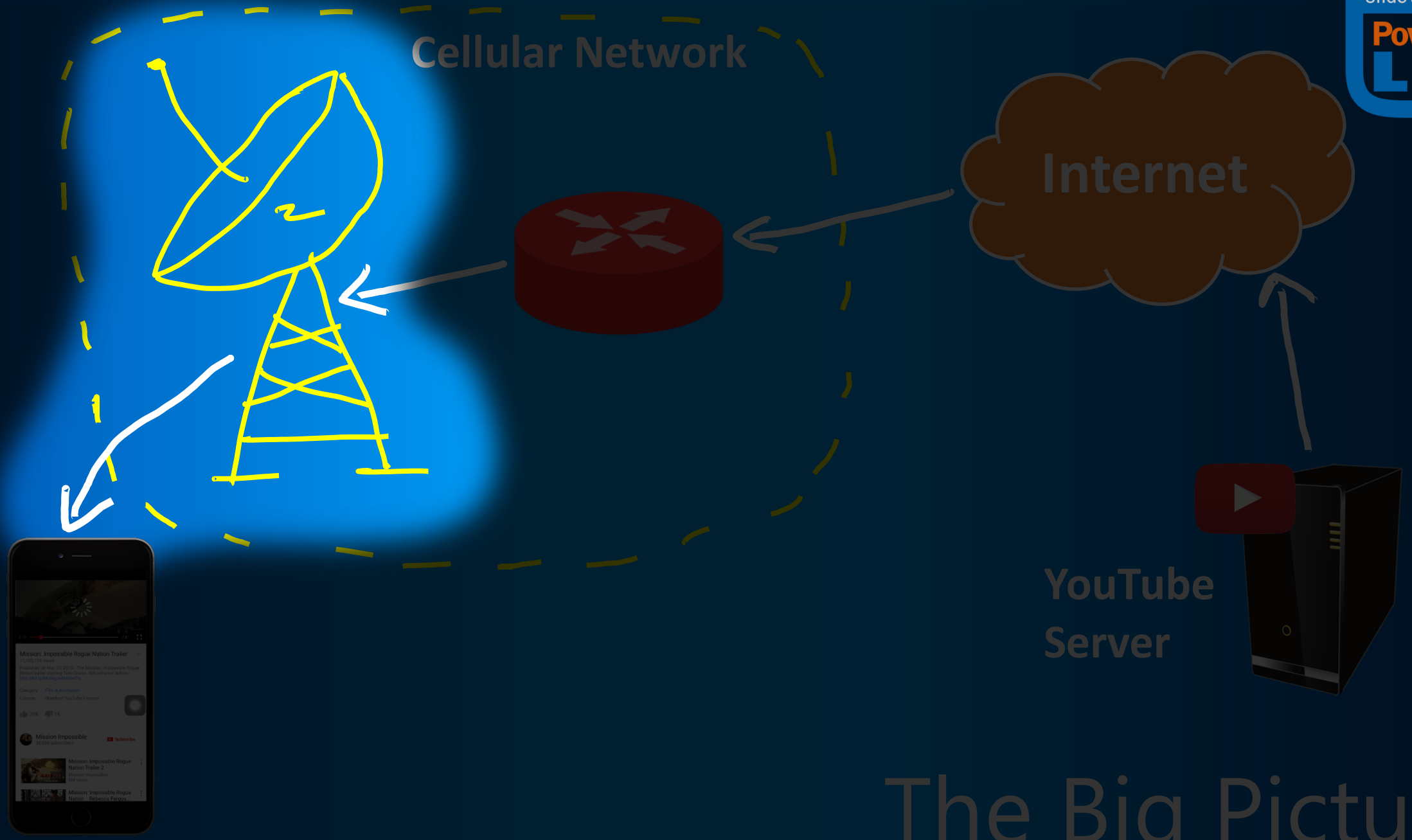



Mission: Impossible Rogue Nation Trailer
THE FOLLOWING PREVIEW HAS BEEN APPROVED FOR
APPROPRIATE AUDIENCES
BY THE MOTION PICTURE ASSOCIATION OF AMERICA, INC.
www.filmratings.com
www.mpaa.org
0:01
2:41

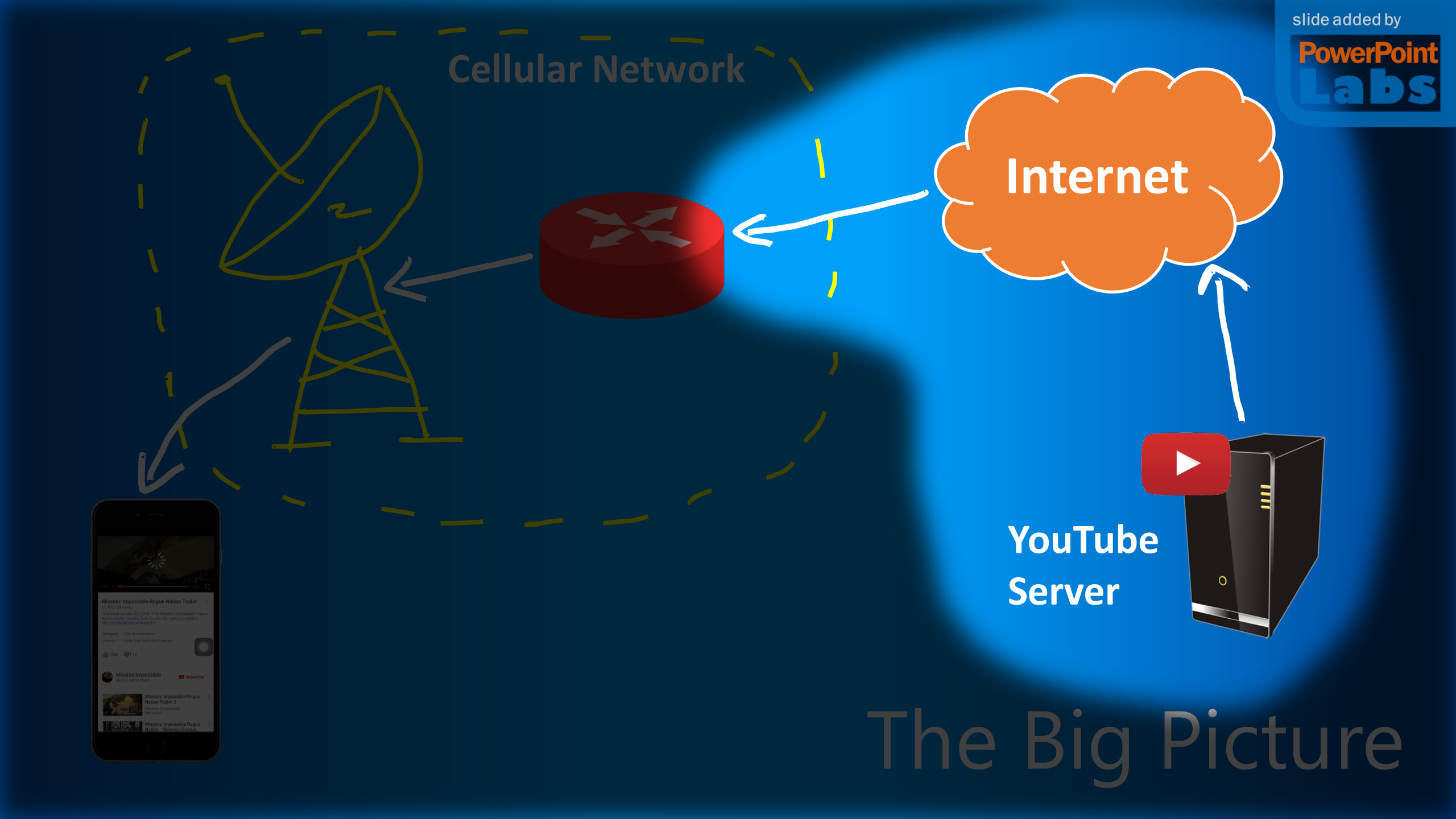

Mission: Impossible Rogue Nation Trailer
0:19
2:41



The Big Picture



The Big Picture



The Big Picture

Where is the Bottleneck?

Where is the Bottleneck?

Why Detect?

Wireless

Alternate connection (e.g., WiFi)

Downsize media content

WAN

Route around the bottleneck

Pick a different replica

PF Scheduler

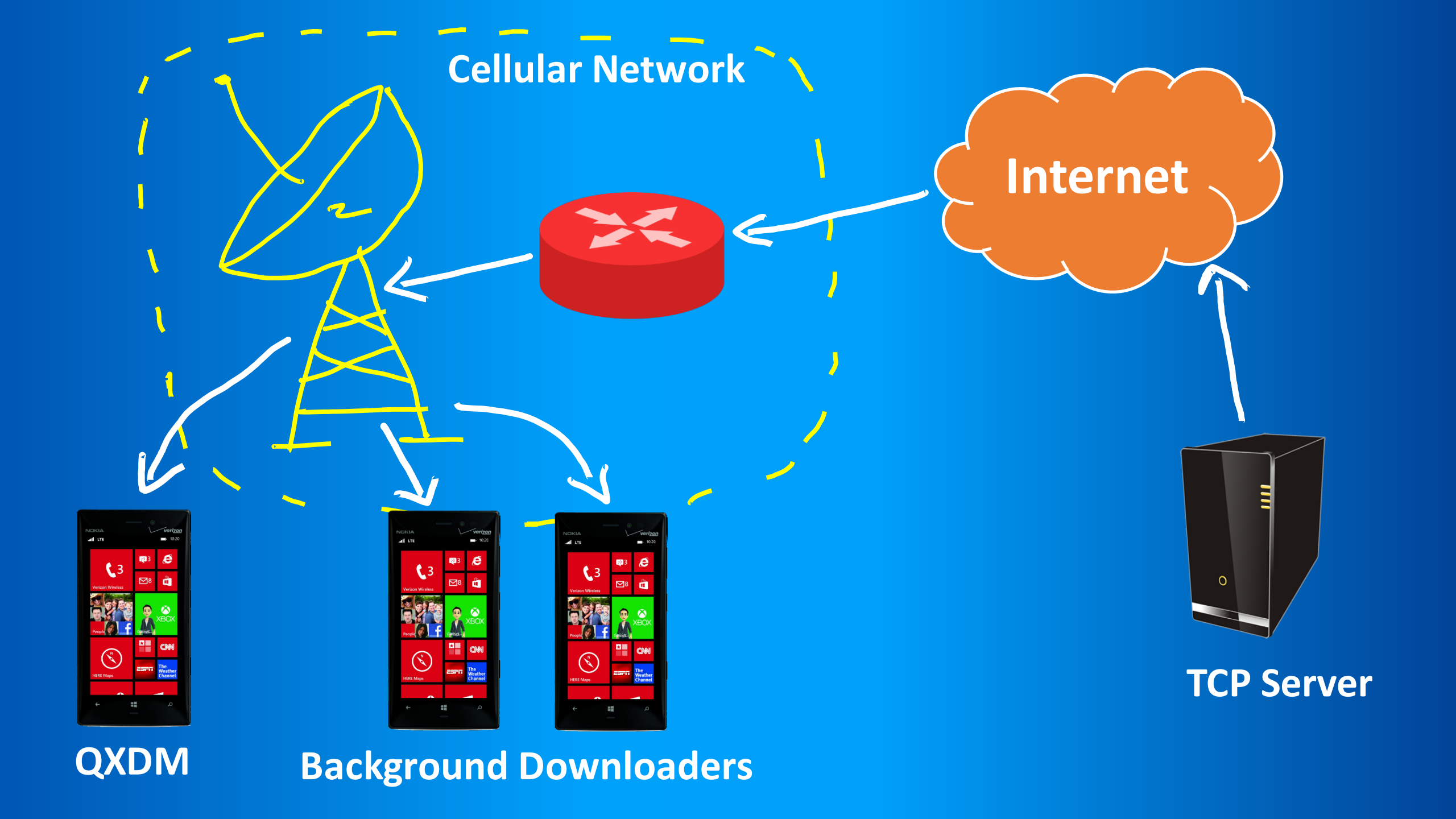
PF Scheduler

Packet scheduler in cellular base stations

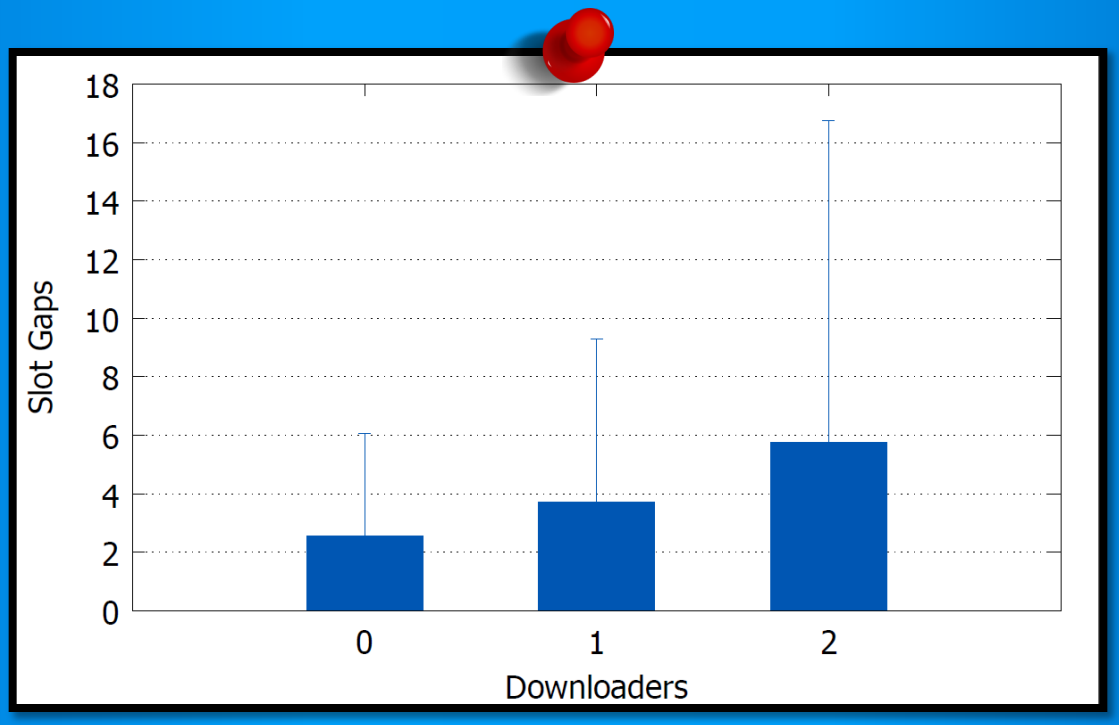
Per-device vs FIFO queues

Fairness vs no notion of fairness

Existing tools are unusable

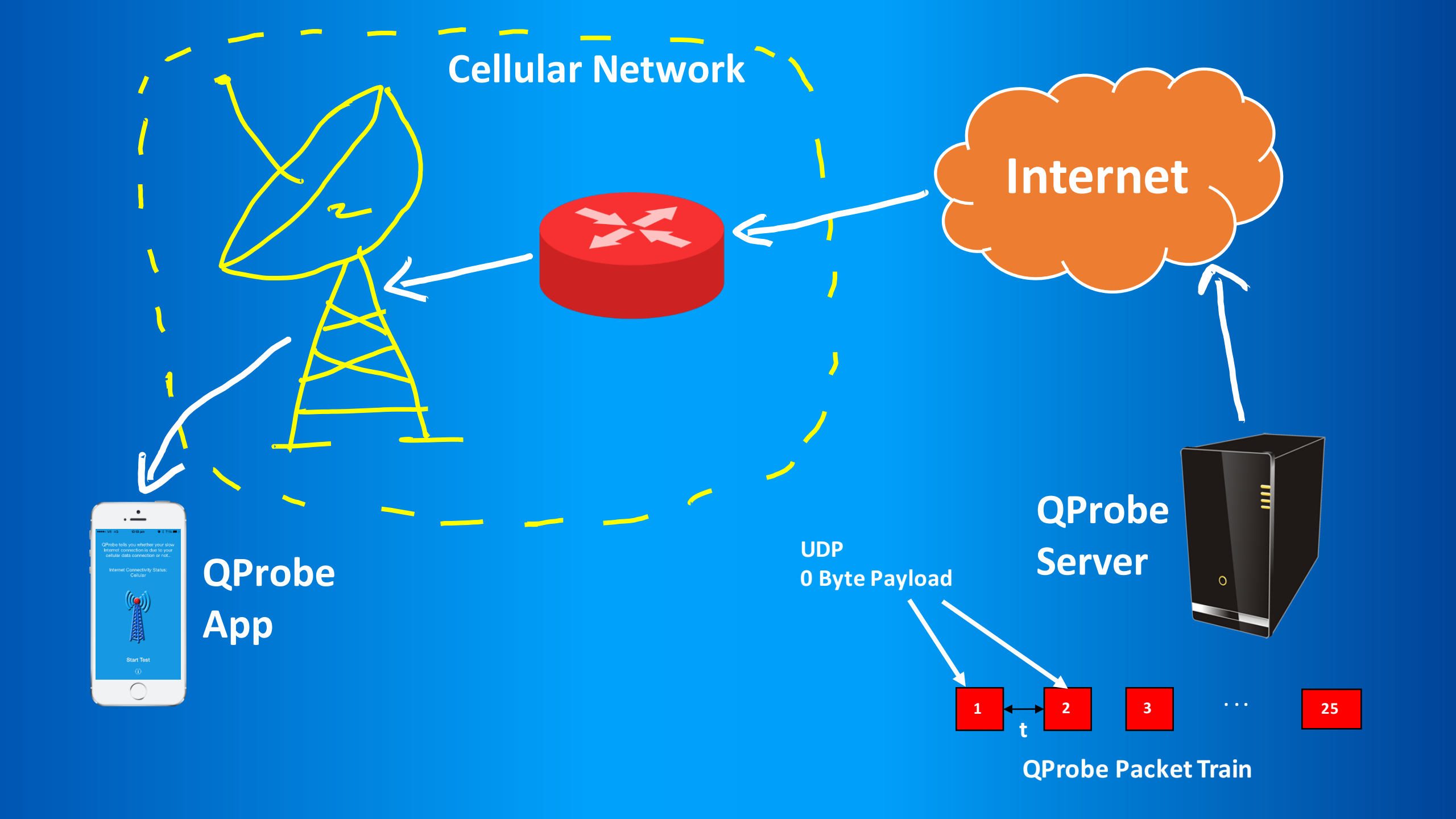

Cellular Network
Internet
TCP Server
QXDM
Background Downloaders

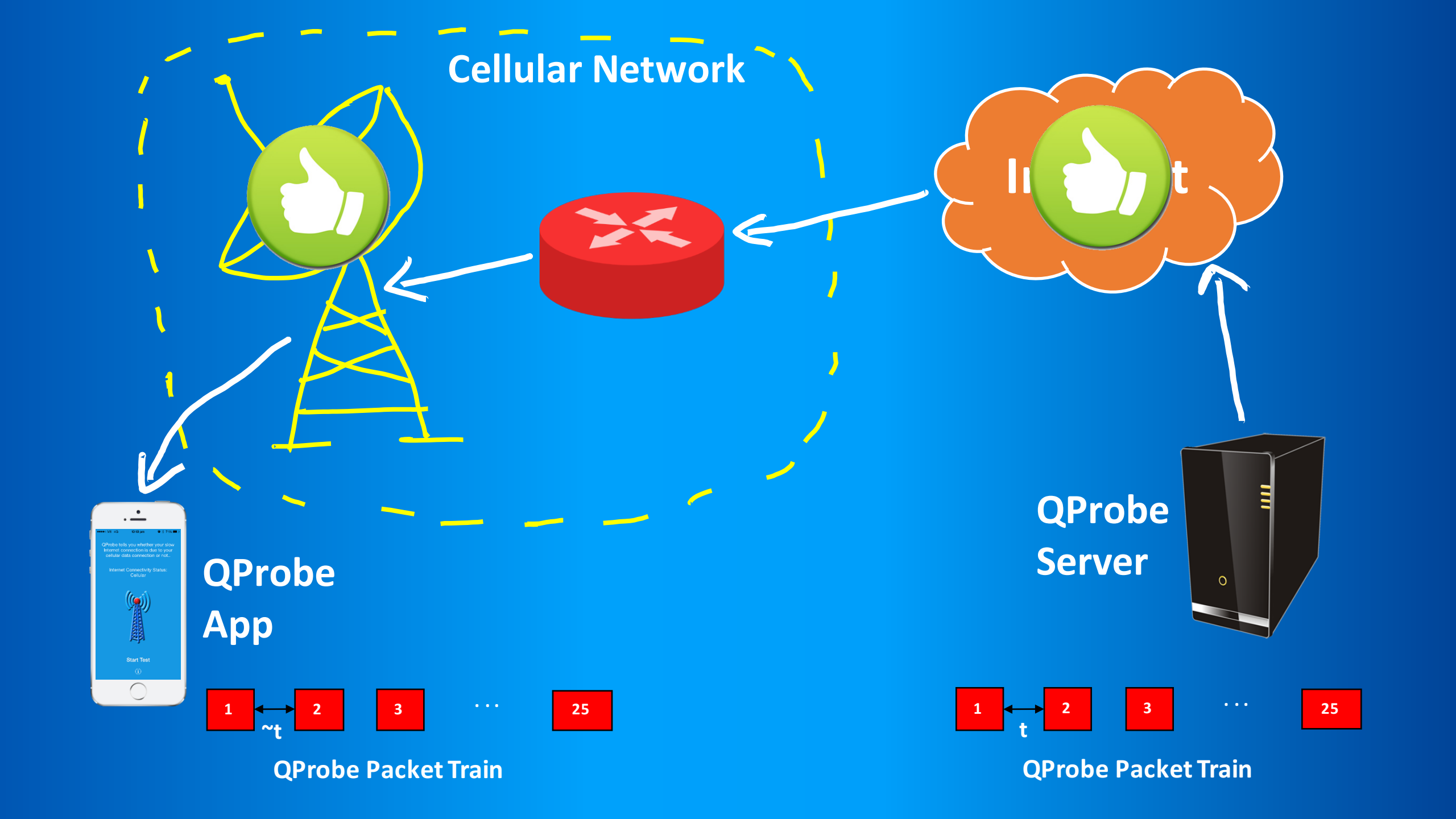
Effect of base station load on slot gaps

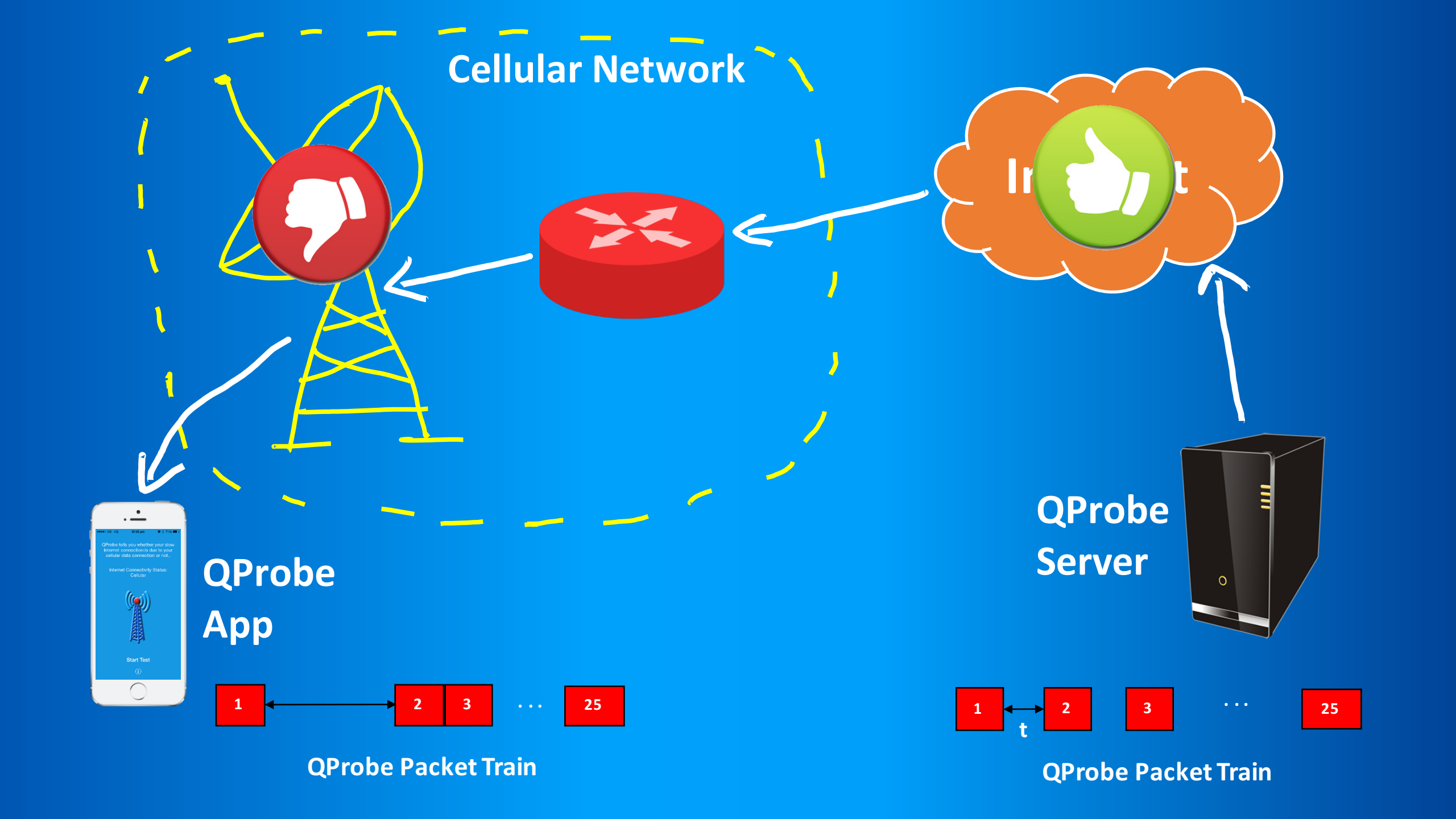


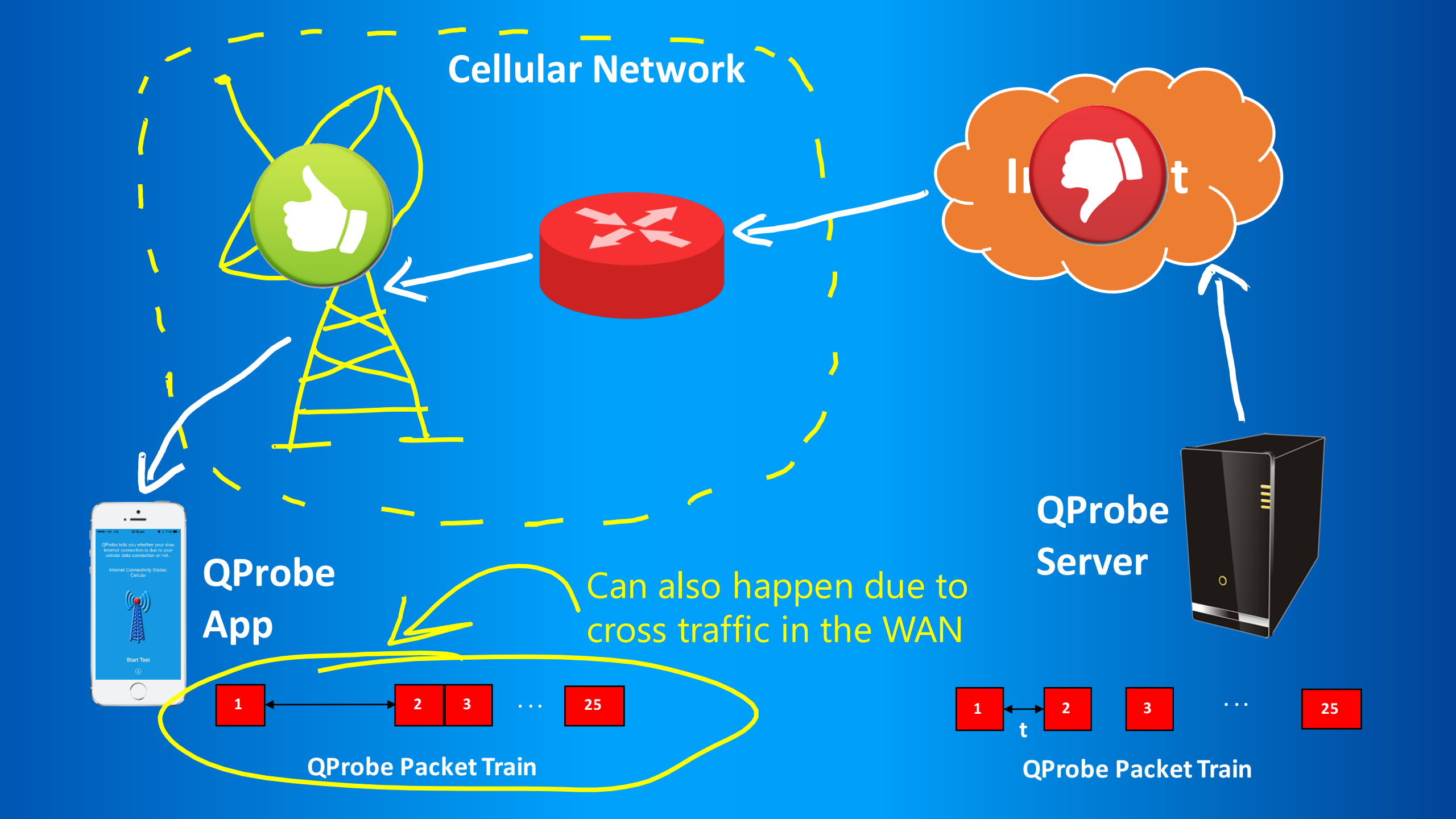
Scheduling frequency decreases with increasing load at the base station

QProbe Design

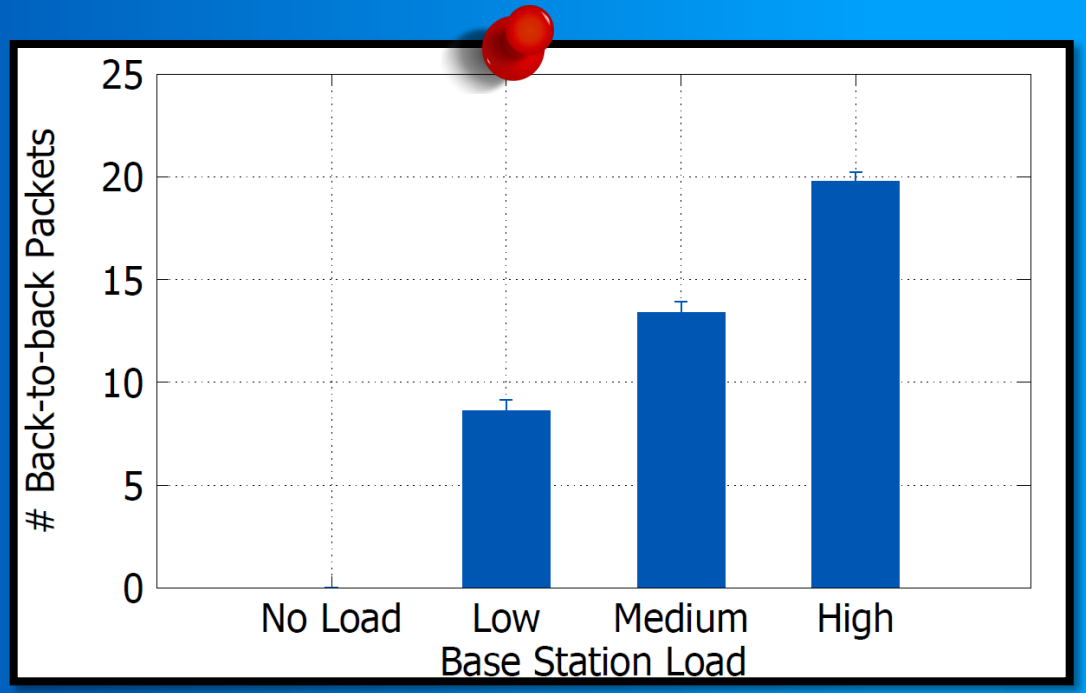

Cellular Network
Internet
QProbe
App
QProbe
Server
UDP
0 Byte Payload
1
2
3
...
25
t
QProbe Packet Train


Cellular Network
QProbe
App
QProbe
Server
1
2
3
...
25
~t
QProbe Packet Train
1
2
3
...
25
t
QProbe Packet Train

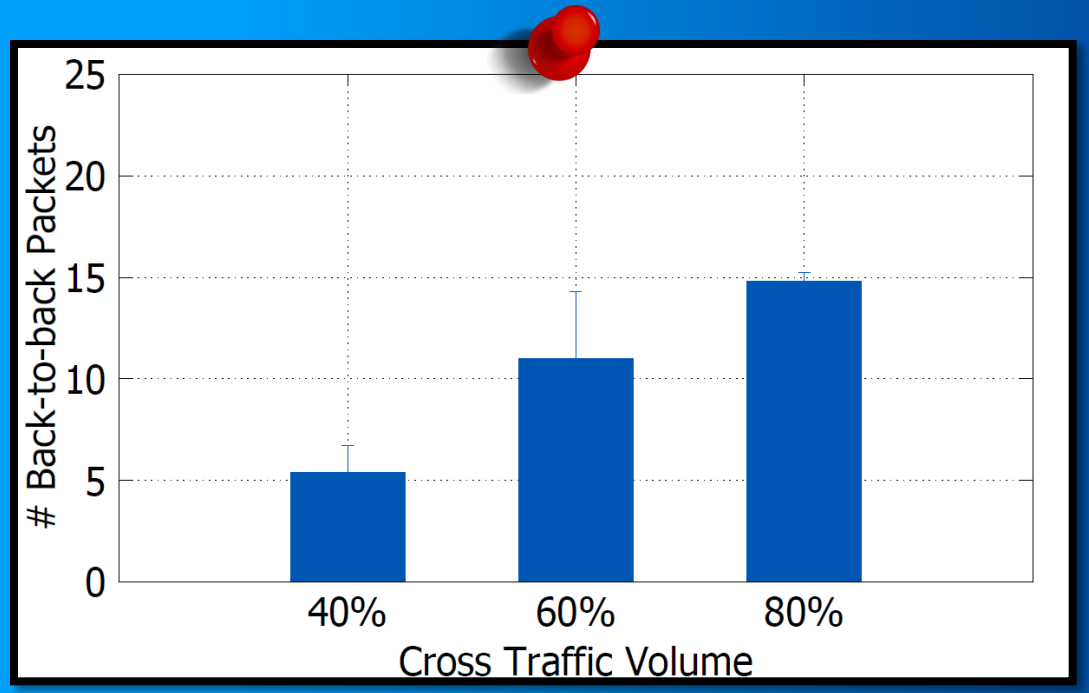

Cellular Network
QProbe
App
QProbe
Server
1
2
3
. . .
25
1
t
2
3
. . .
25
QProbe Packet Train
QProbe Packet Train


Cellular Network
QProbe App
QProbe Server
Can also happen due to cross traffic in the WAN
1
2
3
25
QProbe Packet Train
1
t
2
3
25
QProbe Packet Train

#Back-to-back packets for Wireless and WAN bottlenecks

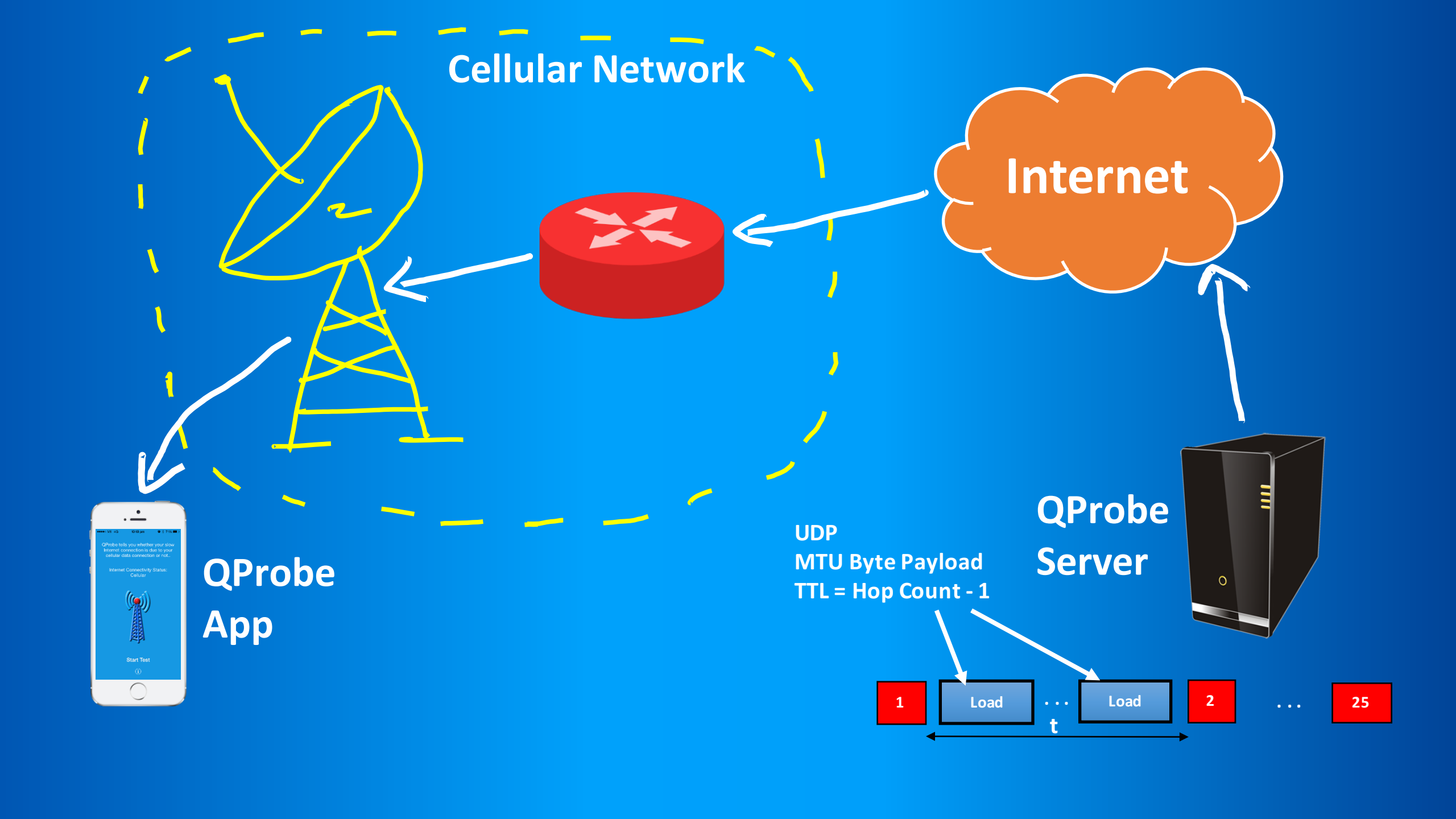


Wireless bottleneck

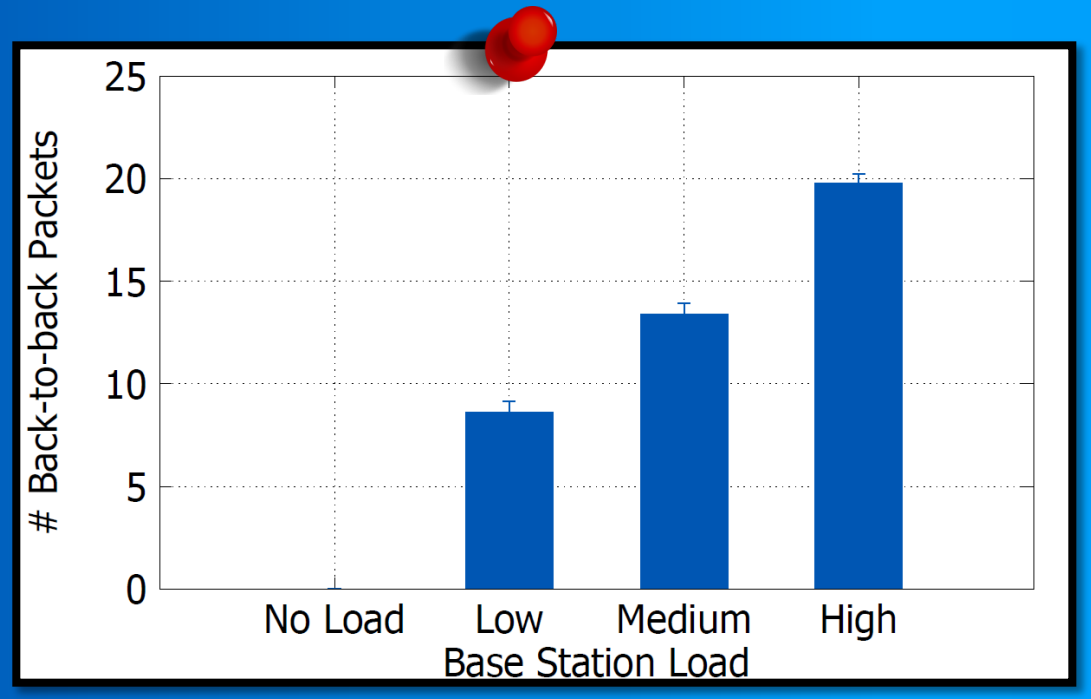


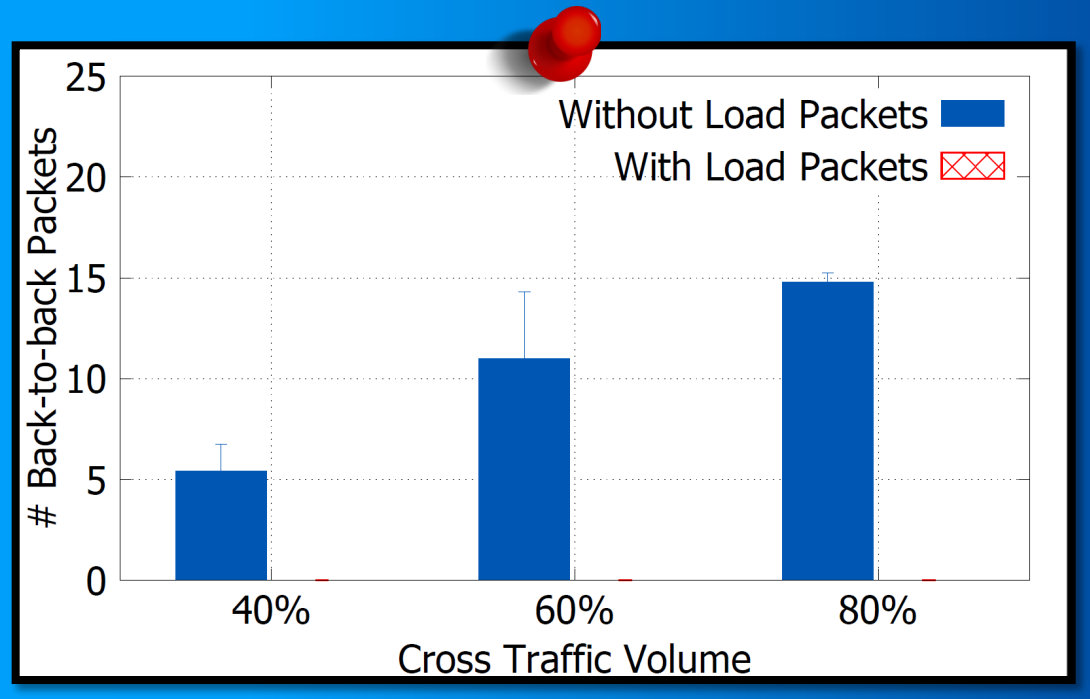
WAN bottleneck

#back-to-back packets, itself, can't accurately detect the bottleneck location.


Cellular Network
Internet
QProbe
App
QProbe tells you whether your slow Internet connection is due to your cellular data connection or not.
Internet Connectivity Status:
Cellular
Start Test
UDP
MTU Byte Payload
TTL = Hop Count - 1
QProbe
Server
1
Load
. . .
Load
2
. . .
25
t

#Back-to-back packets for Wireless and WAN bottlenecks

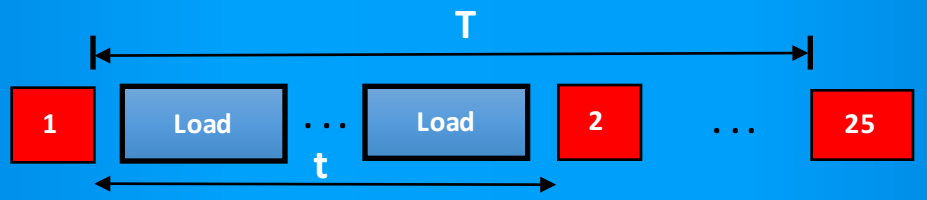




Wireless bottleneck

WAN bottleneck

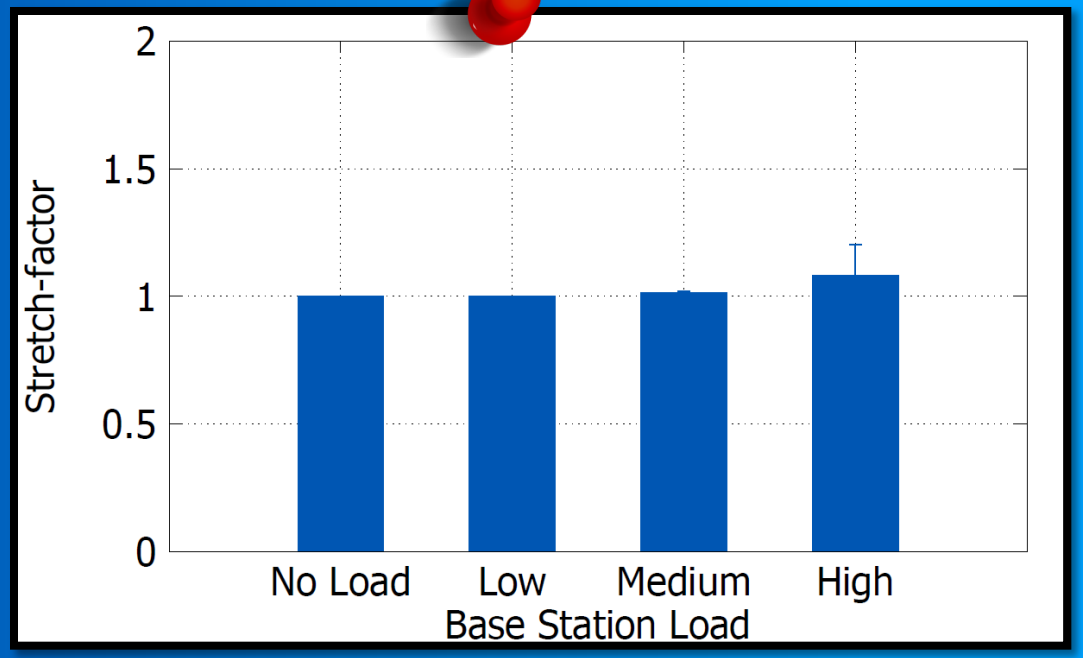
With load packets, #back-to-back packets can detect wireless bottlenecks.



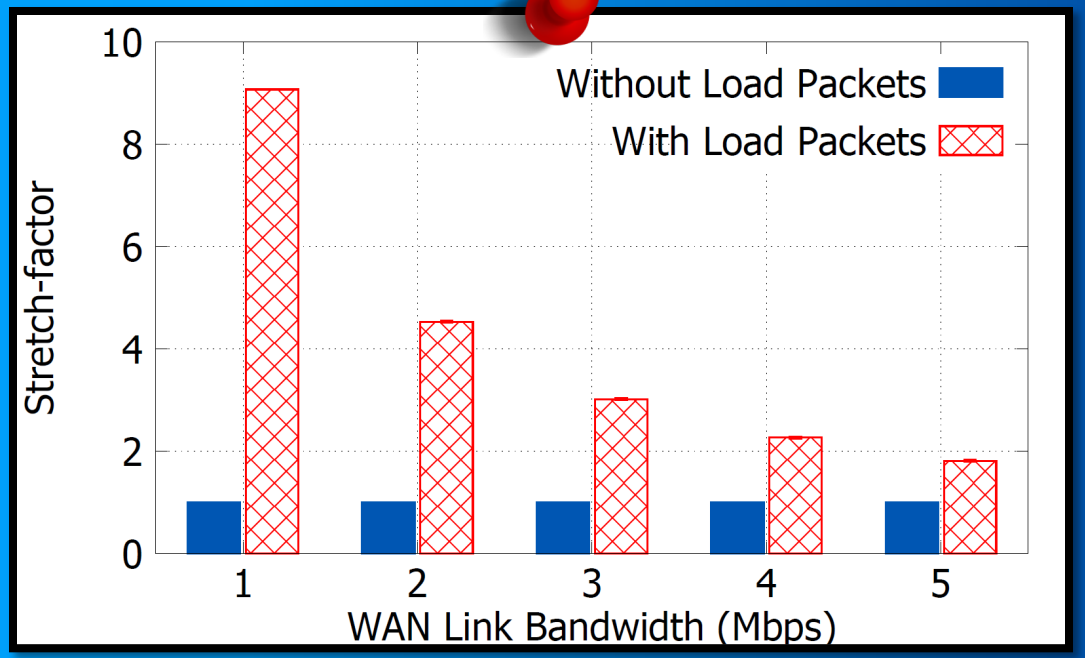
Thin WAN Pipe

$$\text{Stretch-factor} = \frac{\sum \text{Received gaps}}{\sum \text{Sent gaps}}$$

Stretch factors for Wireless and WAN bottlenecks



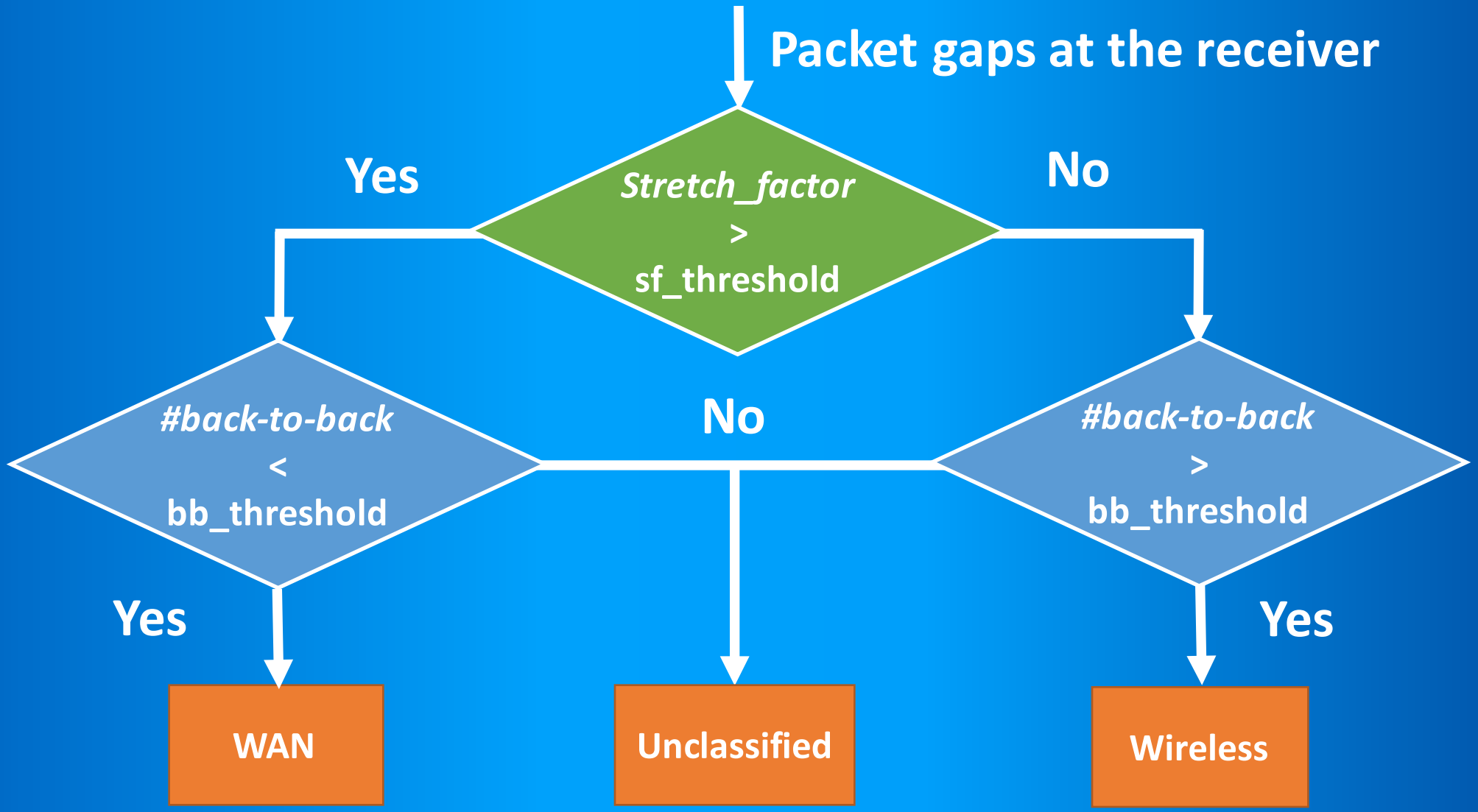
Wireless bottleneck



WAN bottleneck

Load packets increases the stretch-factor. This allows us detect WAN bottlenecks.

QProbe Algorithm



Evaluation

Evaluation

Controlled Experiments

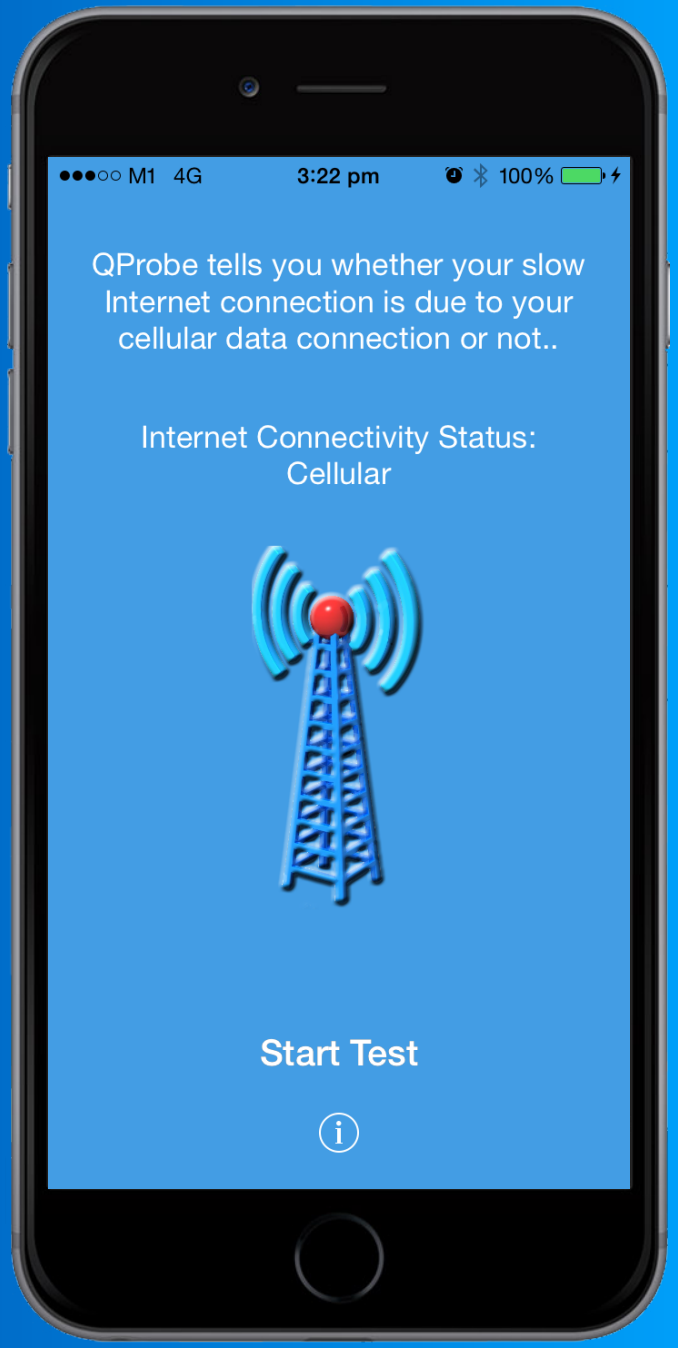
~500 runs for which the ground truth is known

Classification model using a 10-cross validation decision tree

Classification accuracy: 97.4%

Measurement Study

Measurement Study



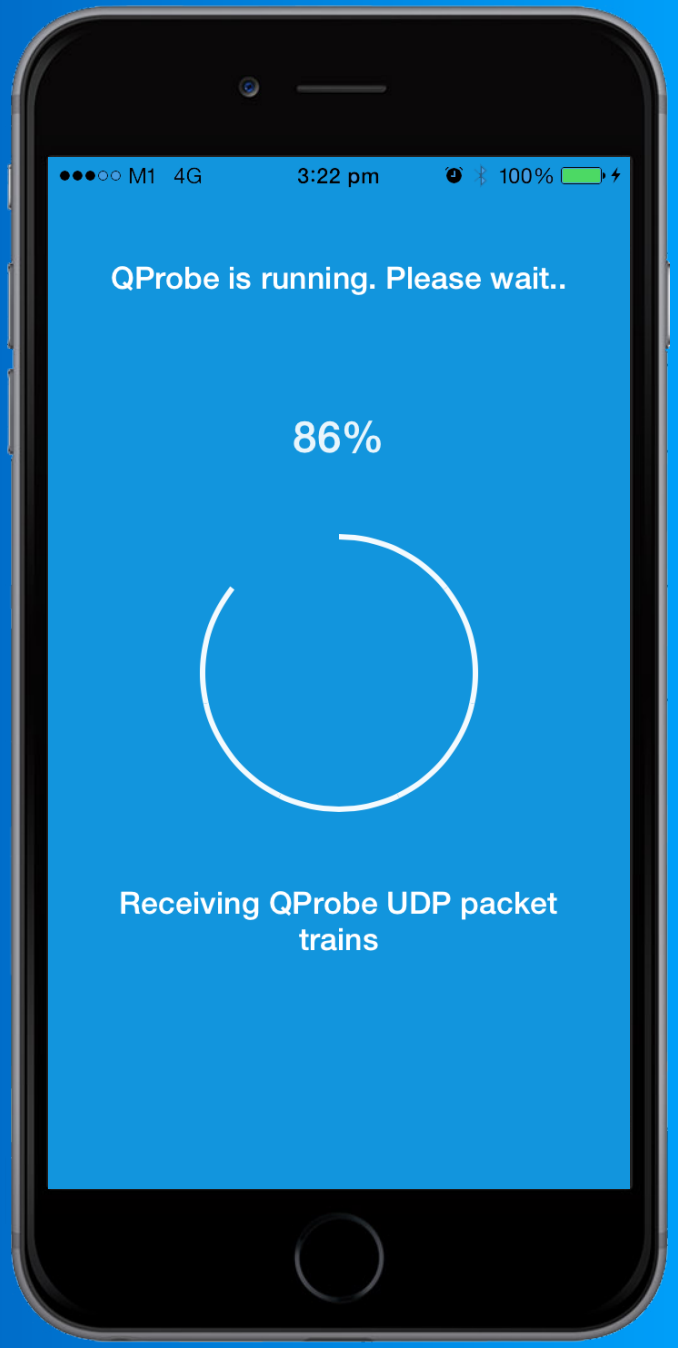
iPhone App implementation

15 well-provisioned Azure servers

51 PlanetLab servers

2 months of data

8116 runs of QProbe



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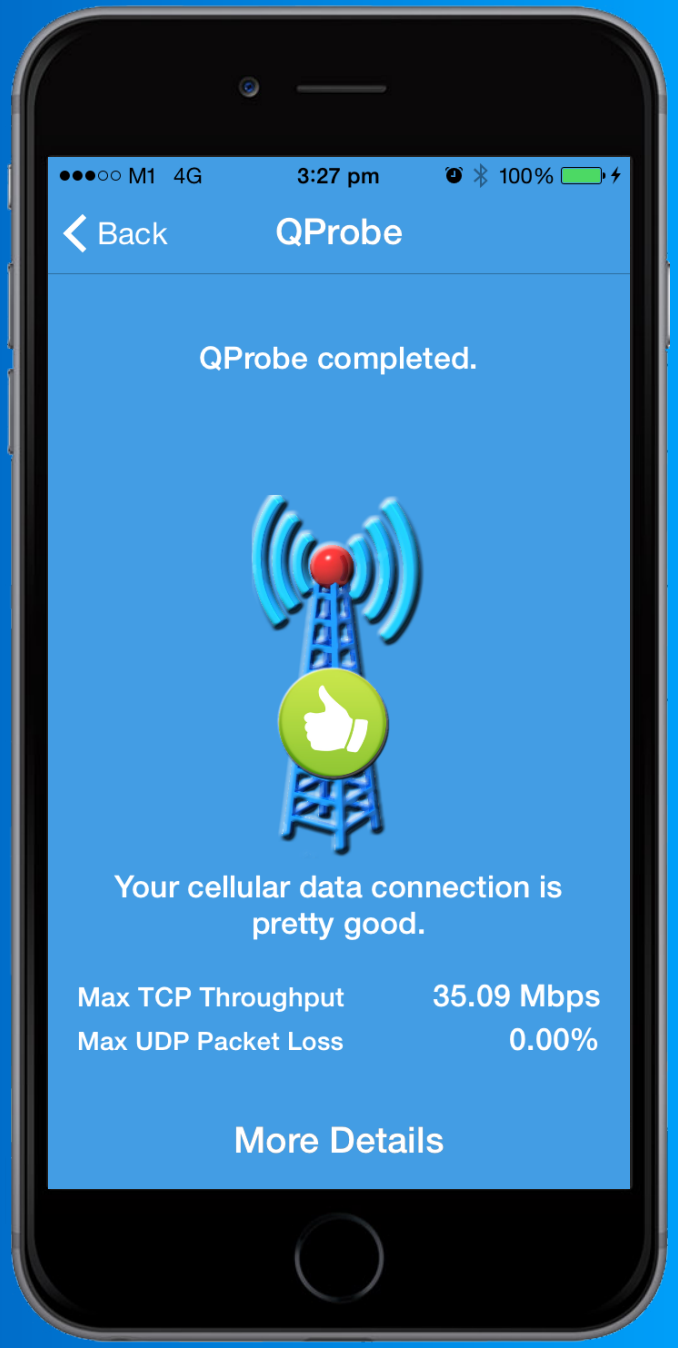

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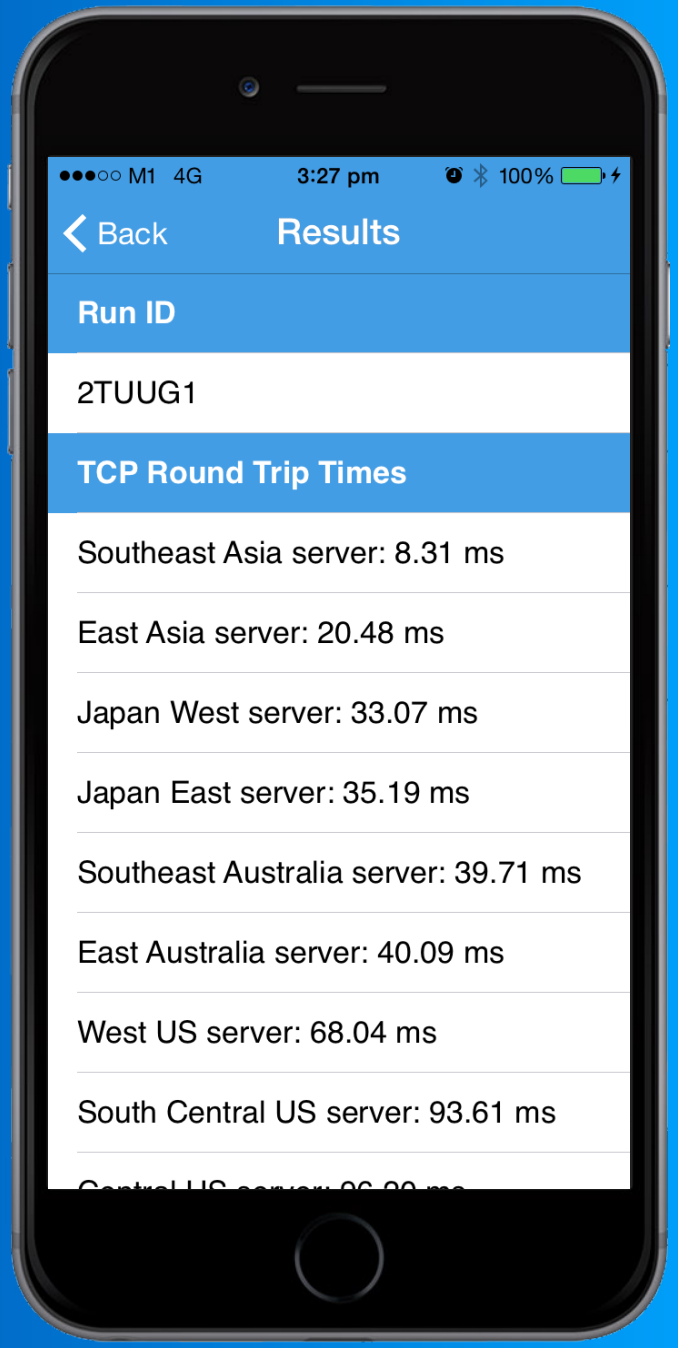


iPhone App implementation

15 well-provisioned Azure servers

51 PlanetLab servers

2 months of data

8116 runs of QProbe

642 Users | 33 Countries | 51 ISPs

Summary of QProbe Runs

Technology	Runs	Wireless	WAN
3G	2573	215 (8.35%)	97 (3.77%)
LTE	5480	441 (8.05%)	837 (15.27%)

QProbe Results (3G)

3G Classified Runs: 84.3%

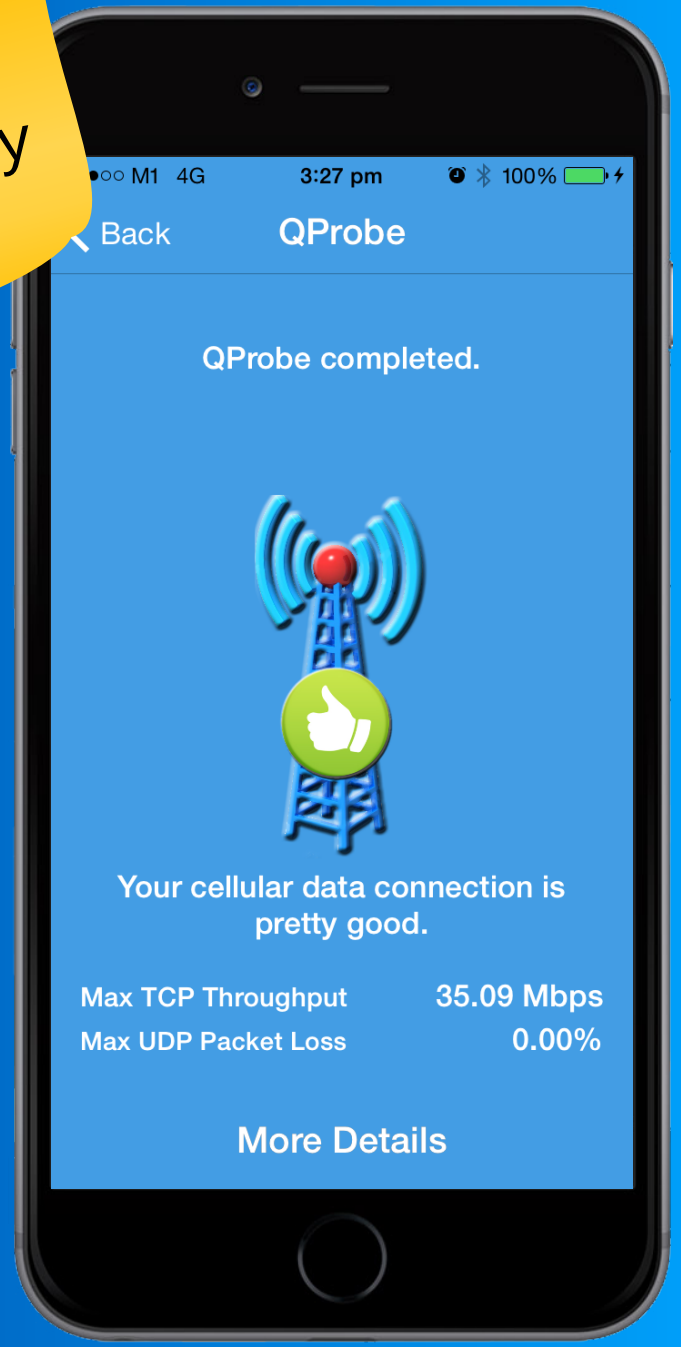
		QProbe Classification	
Ground Truth		Wireless	WAN
Wireless	187	161 (86.1%)	26 (13.9%)
WAN	76	13 (17.11%)	63 (82.89%)

QProbe Results (LTE)

LTE Classified Runs: 81.2%

		QProbe Classification	
Ground Truth		Wireless	WAN
Wireless	330	307 (93.03%)	23 (6.97%)
WAN	708	116 (16.38%)	592 (83.62%)

Summary



QProbe: lightweight, platform independent, bottleneck detection technique

Uses less than 4KB of data and runs in ~700ms

Extensive evaluations show >85% bottleneck detection accuracy

Data and code available at
www.comp.nus.edu.sg/~nimantha/qprobe.html

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