An open loop congestion management scheme in mobile networks

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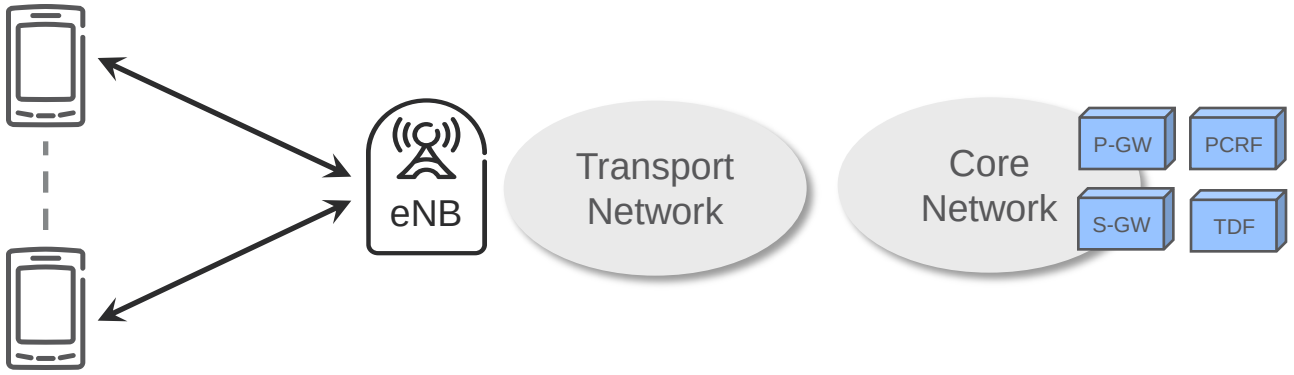
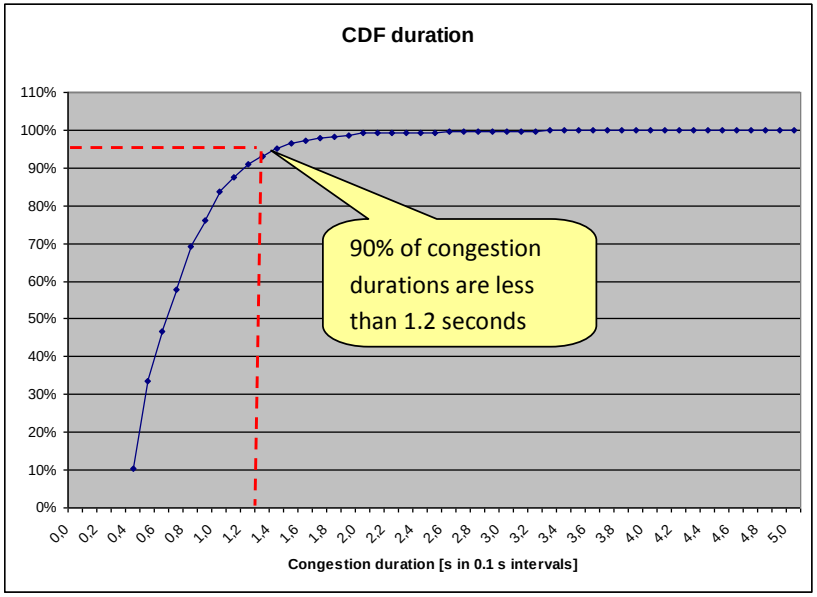
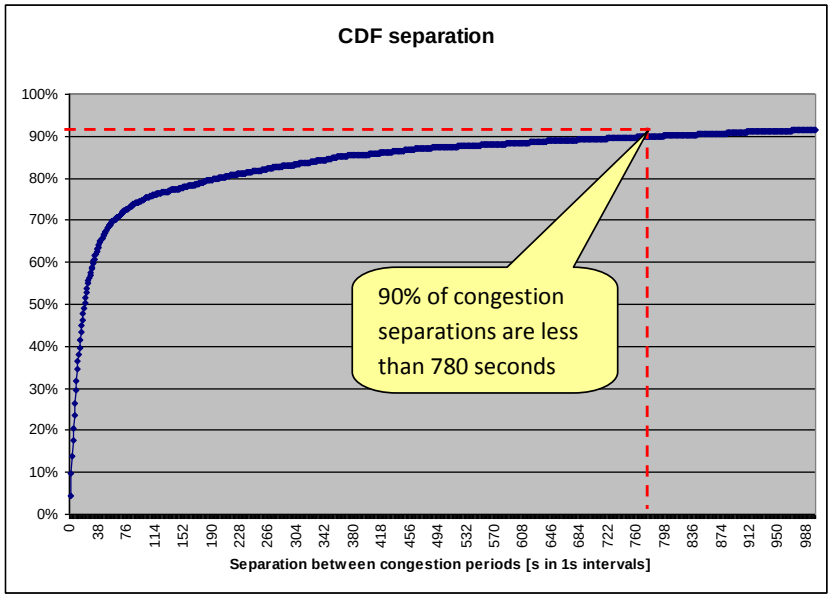
Congestion management in mobile networks

- Congestion: the demand for (RAN) resources exceeds the available (RAN) capacity for a period of time
- Congestion may lead to decreased user experience
- Scope:
  - Make use of available resources efficiently in congestion
  - Handling of user plane traffic when RAN congestion occurs based on e.g.
    - Subscription of the user
    - Type of content
    - Application



Congestion characteristics in mobile networks





- Measured on a live network
- Congestion periods are short
- Congestion periods are relatively frequent

- Source of the figures: 3GPP TR 22.805

Quality of Service in mobile networks

- Based on bearers (association between the PDN GW and the UE)
- QCI (QoS Class Identifier) value determines required treatment (delays, guaranteed bitrate, priority.. etc)
- 9 standardized QCI values

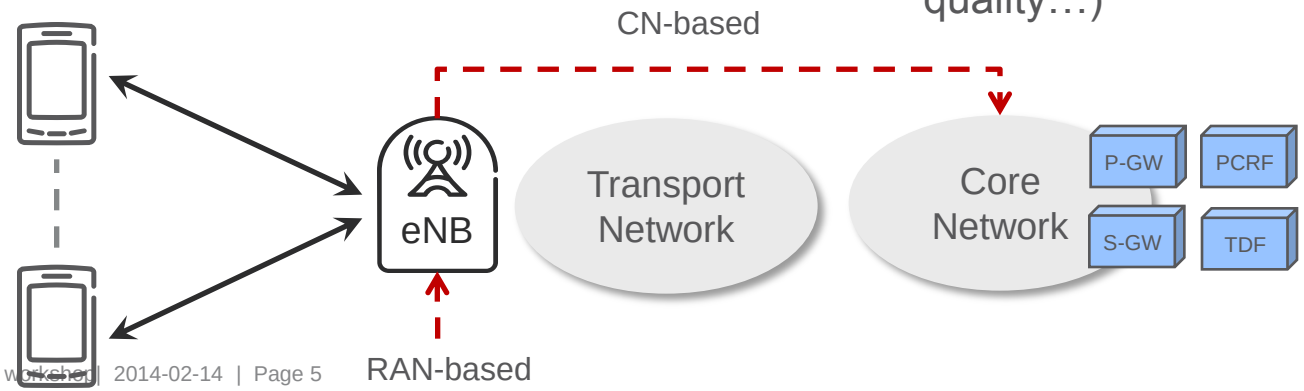
QCI	Resource type	Priority	Packet delay budget	Packet error loss rate
1	GBR	2	100 ms	10^{-2}
2	GBR	4	150 ms	10^{-3}
3	GBR	3	50 ms	10^{-3}
4	GBR	5	300 ms	10^{-6}
5	Non-GBR	1	100 ms	10^{-6}
6	Non-GBR	6	300 ms	10^{-6}
7	Non-GBR	7	100 ms	10^{-3}
8	Non-GBR	8	300 ms	10^{-6}
9	Non-GBR	9	300 ms	10^{-6}

From 3GPP TS 23.203

CN-based vs RAN-based congestion management

- **Core Network based (closed loop)**
  - Congestion information sent from RAN to CN
  - CN takes specific actions based on congestion feedback
- Challenges
  - Inherent delay in the feedback loop
  - Under-utilization might occur
  - Prone to potentially high signalling
- Advantages
  - Centralized management

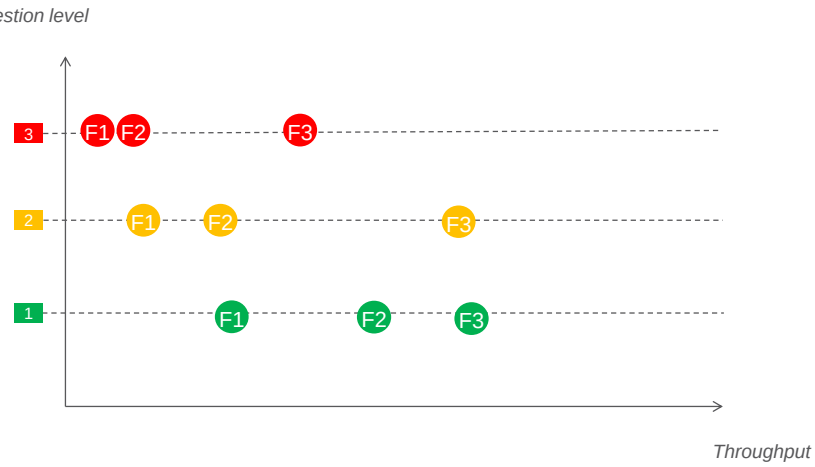
- **Radio Access Network Based (open loop)**
  - Core Network marks the packets to indicate preferred treatment
  - Congestion mitigation is done in the RAN
- Challenges
  - Packet marking
- Advantages
  - Congestion handled where it occurs
    - Fast reaction
    - Radio scheduler has the full picture (demands, channel quality…)



FQI – A RAN-based (open loop) congestion management scheme

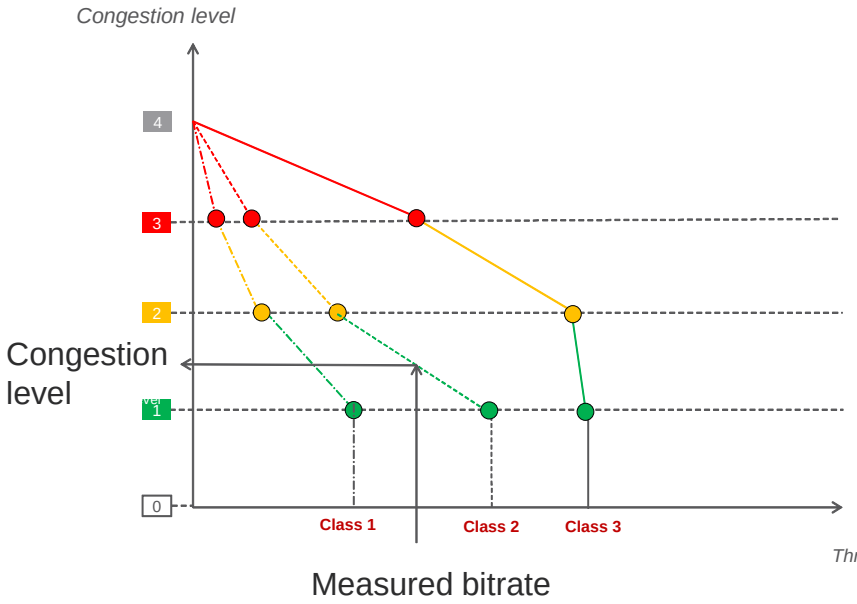
- Downlink data packets are marked with **FQI – Flow QoS Index**
- FQI points to a specific **congestion handling behaviour**
  - E.g. bitrate in a **given congestion level** (e.g. x kbps in “low” congestion, y kbps in “high” congestion)
- QCI and FQI jointly define the treatment of the flow in congestion situations

Throughput targets for flows F1, F2 and F3 in congestion levels 1,2 and 3:



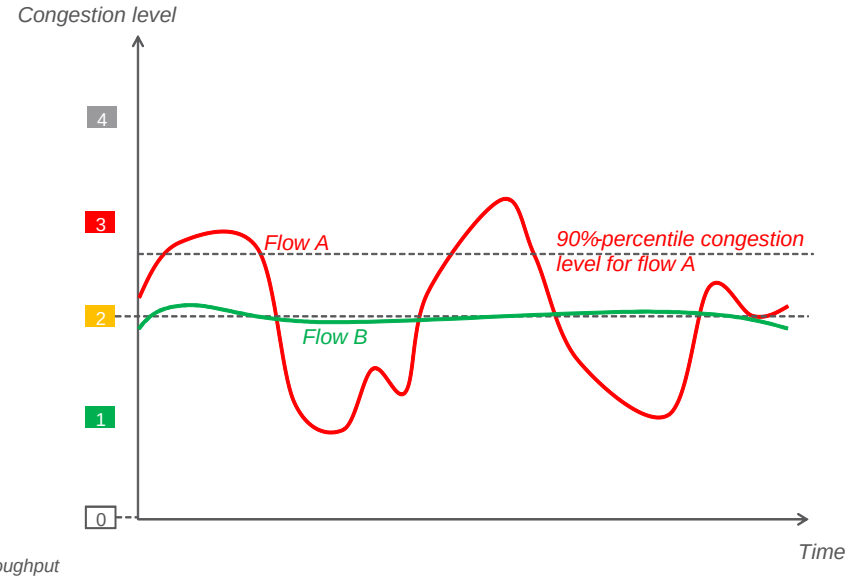
Evaluation - Metrics

Realized bitrate -> congestion level



- Bitrate is translated to congestion level based on the target charts

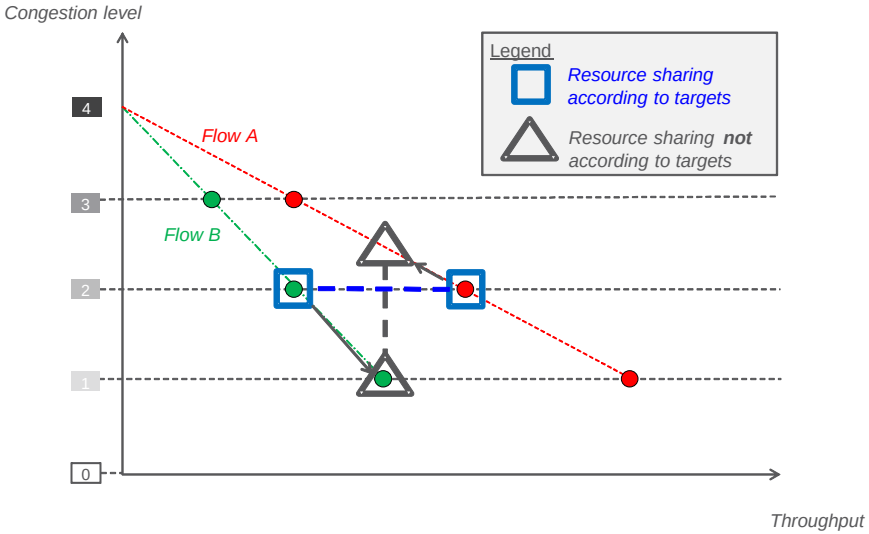
Average vs. 90% congestion level



- Flow A and Flow B has the same average congestion level over time
- 90% percentile congestion level better captures the congestion experience of the user

Evaluation - Metrics

Congestion level for different users

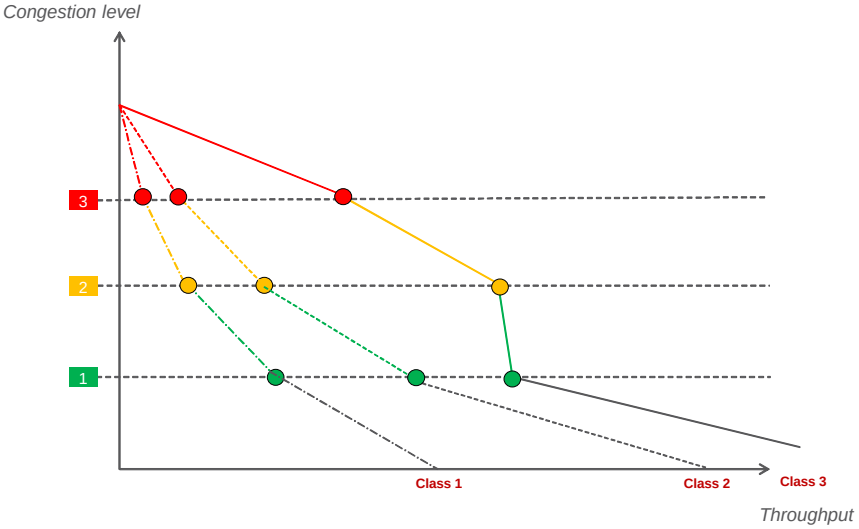


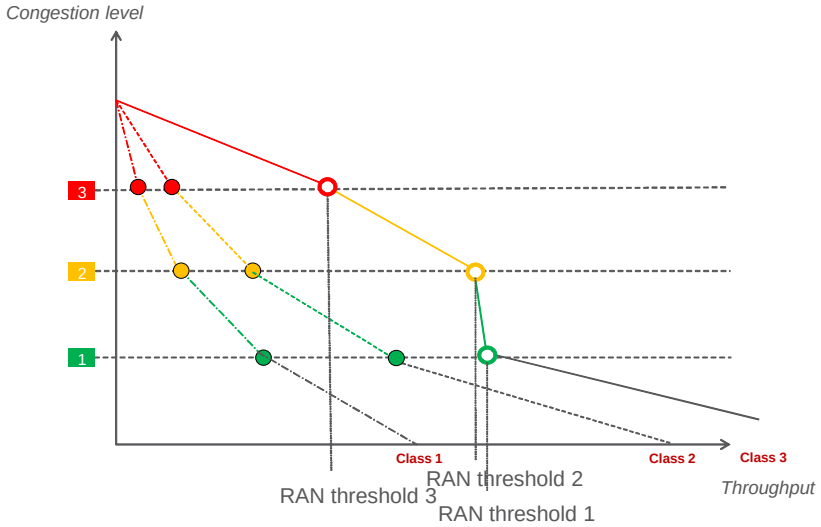
- Average congestion level for situation □ > average congestion level for situation △
- 90% congestion level weighted by the amount of traffic better captures the overall goodness of the resource distribution

- Congestion levels vary over time and between users
- Proposed metric
  - Measure the bitrate for each flow for 1 second
  - Determine the congestion level corresponding to the measured bitrate
  - Calculate the 90% percentile of all the samples, weighted by their bitrates

FQI vs a CN-based scheme

- Two schemes has to work with the same operator targets
- We are interested in how the schemes can follow operator targets

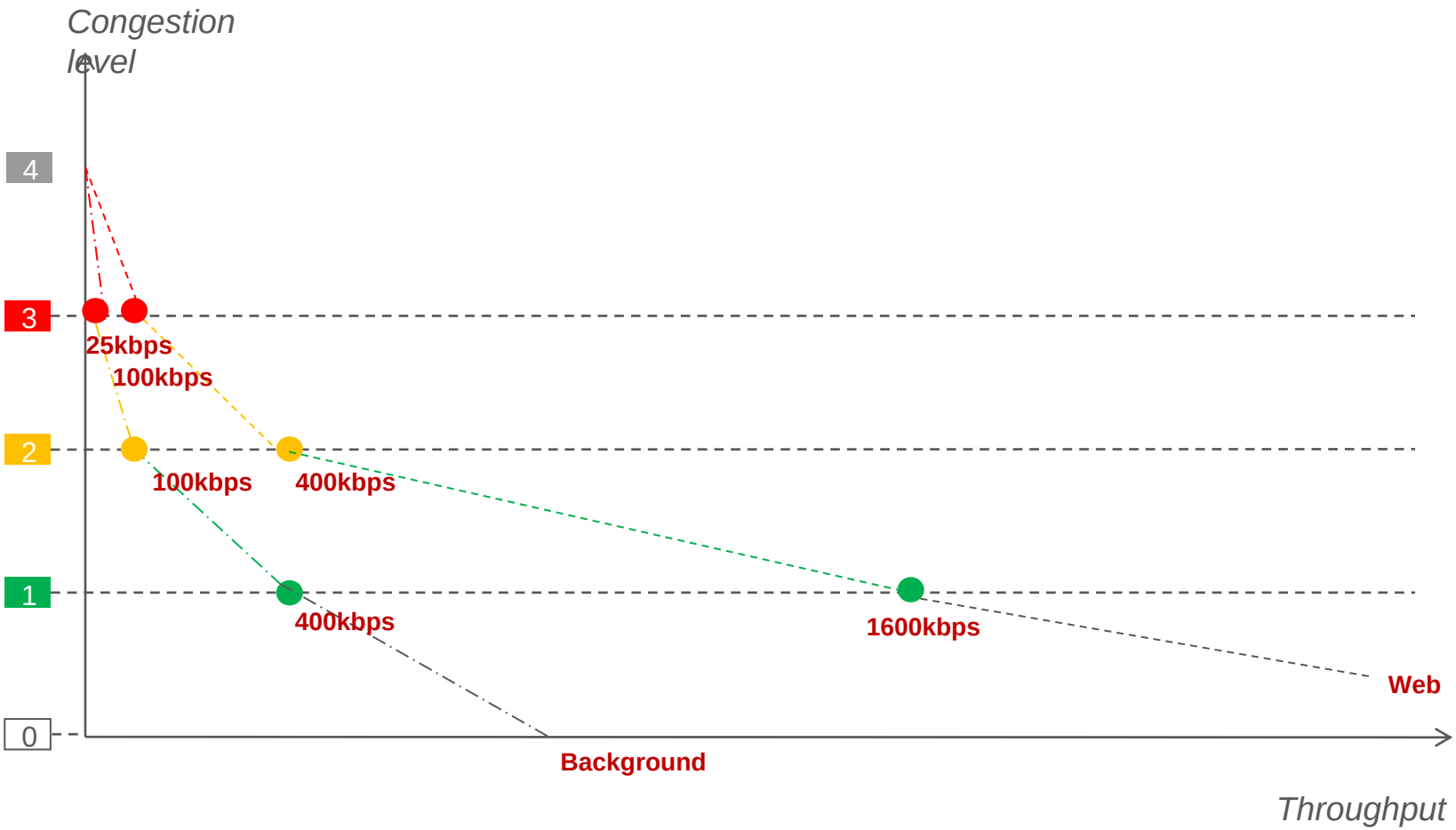




- FQI:
  - Allocate resources to fulfill the lowest congestion level possible
  - Distribute excess resources proportionally

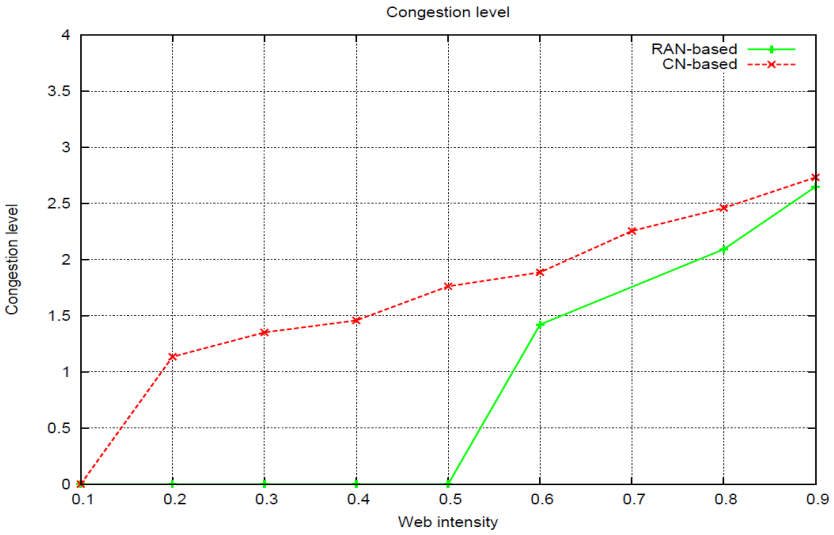
- CN-based scheme:
  - Report the achieved throughput in RAN per flow periodically (e.g. 60 seconds)
  - Use the report to determine overall congestion level
  - Shape the flows in the CN accordingly; all but most important class is shaped
  - RAN distributes resources equally

Example scenario - 1



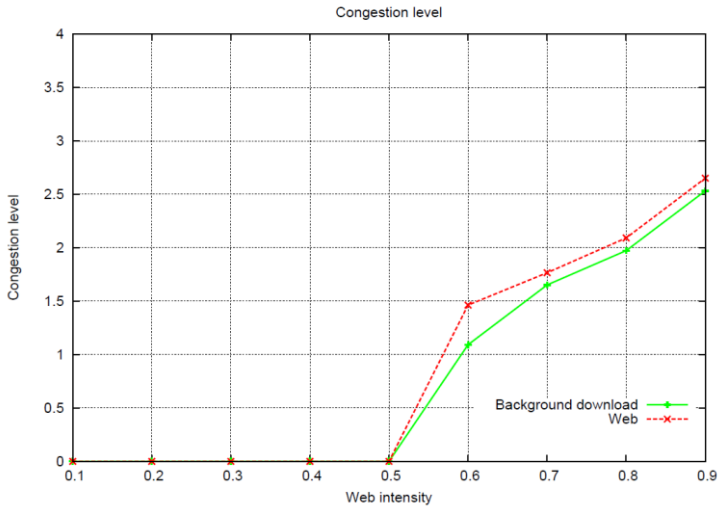
- Web and background FTP downloads
- Web should get significantly higher throughput in all situations

Results – web and background

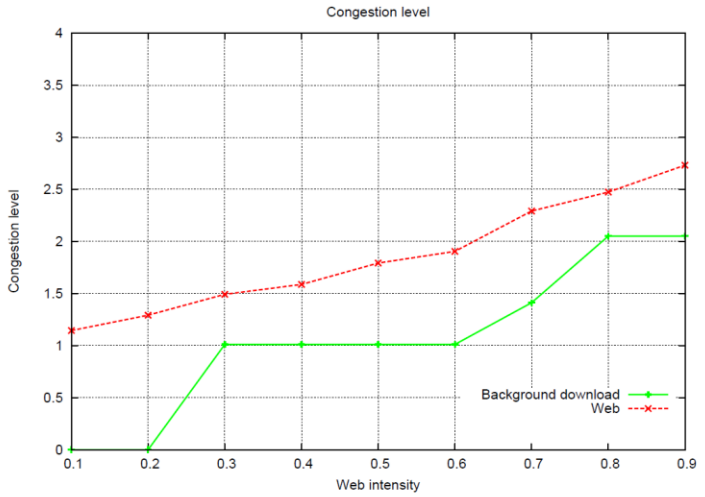


- Main parameters: 20 Mbps cell, 10 background users, web users (news portal) arriving by Poisson
- 90% congestion level is lower with RAN-based (FQI) solution
- FQI has similar congestion levels for both type of flows -> targets succesfully followed
- CN-based approach shows divergent congestion levels for different type of flows

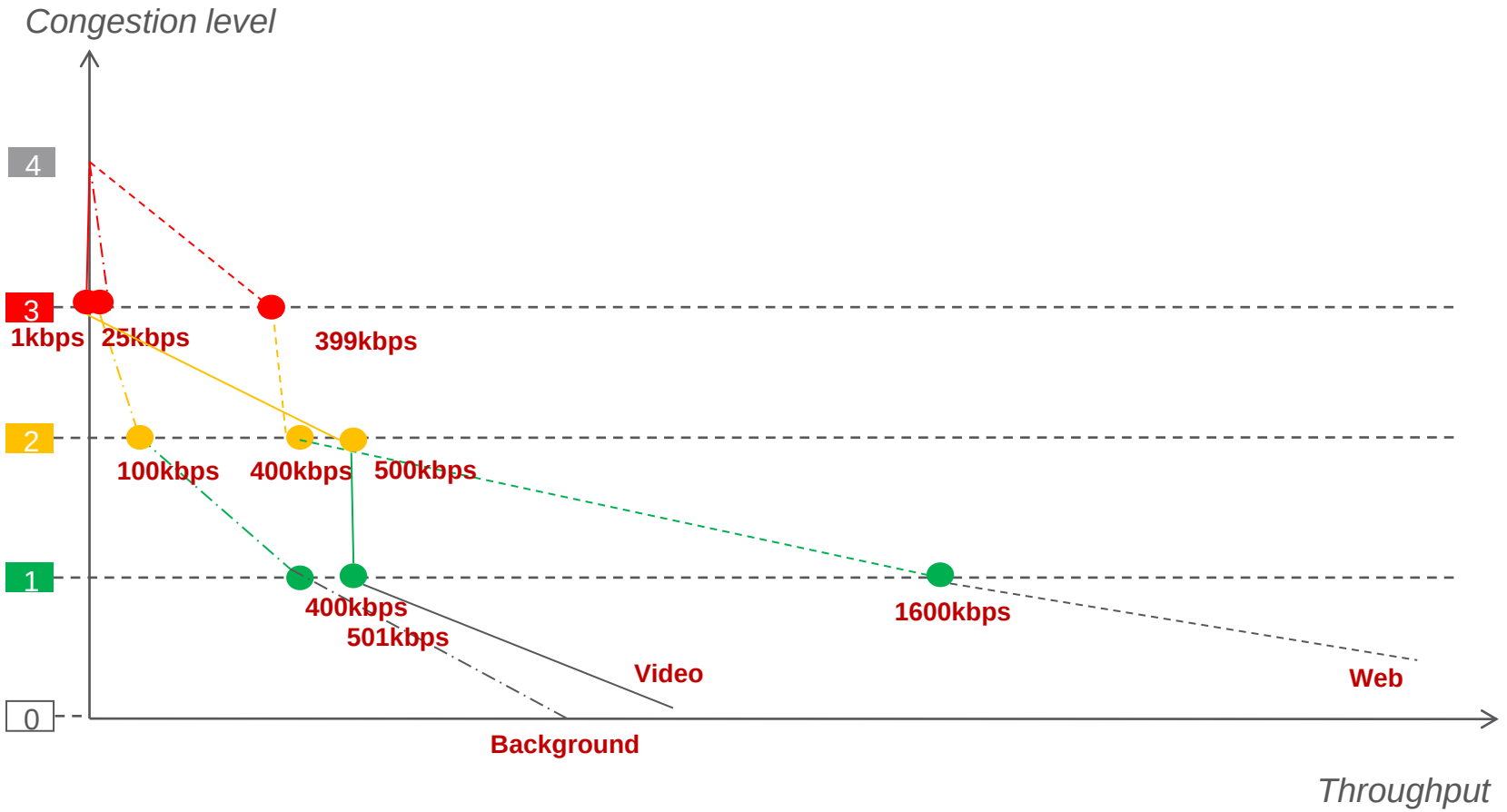
RAN-based (FQI)



CN-based

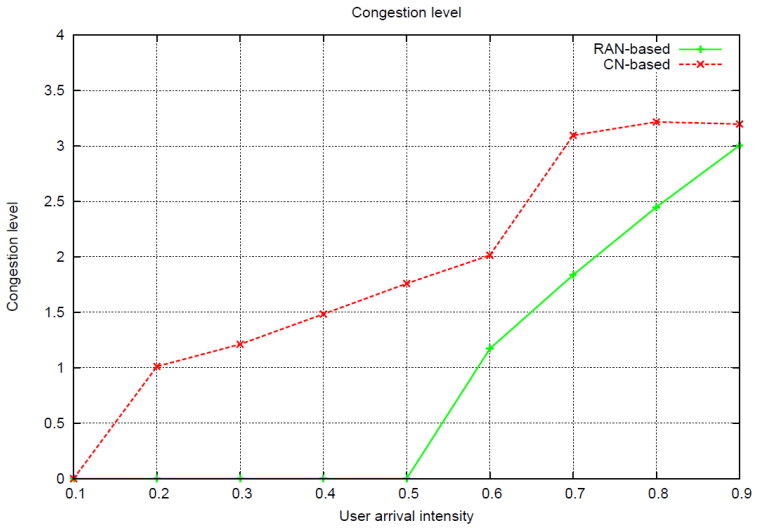


Example scenario - 2



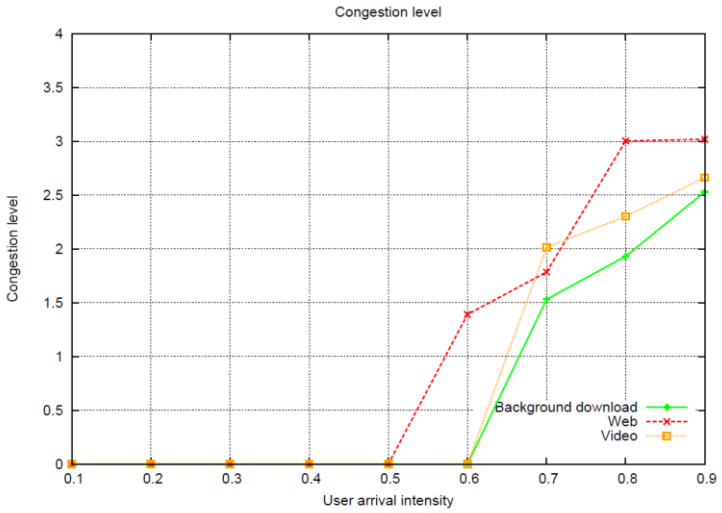
- Web, video and background FTP downloads
- At high congestion video is blocked; at medium congestion web is shaped to protect video flows; at low congestion video is shaped as it does not need higher throughput for continuous playout

Results – web, video and background

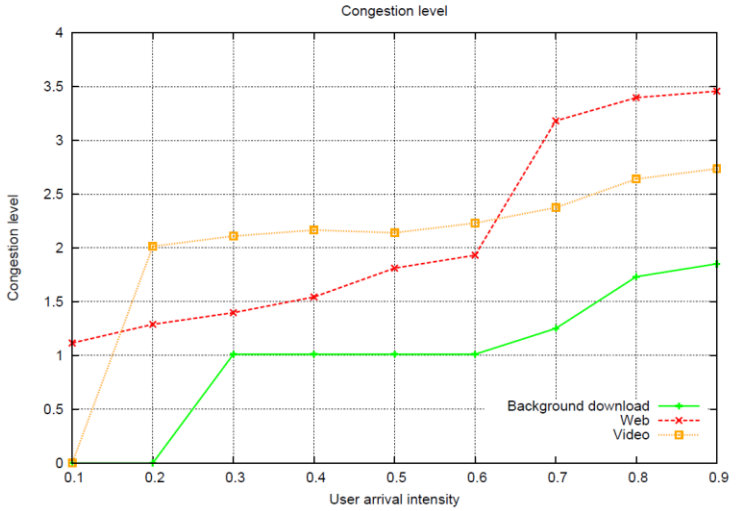


- Main parameters: 20 Mbps cell, 10 background users, 50% web users (news portal) and 50% video users arriving by Poisson; 400 kbit/s video in 12 ~200KB chunks
- 90% congestion level is lower with RAN-based (FQI) solution
- FQI has similar congestion levels for both type of flows -> targets succesfully followed
- CN-based approach shows divergent congestion levels for different type of flows

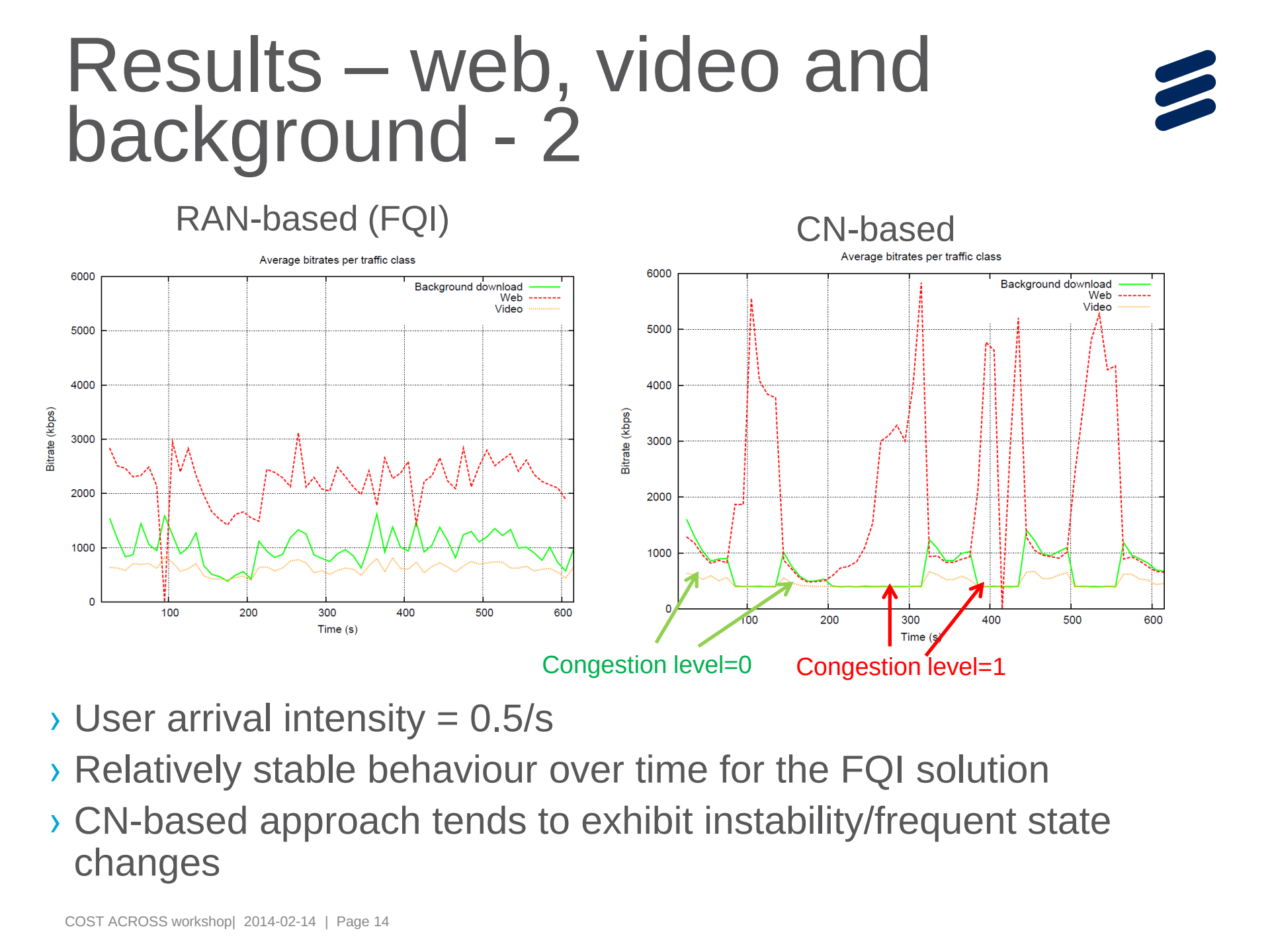
RAN-based (FQI)



CN-based



Results – web, video and background - 2



RAN-based (FQI)

CN-based

- User arrival intensity = 0.5/s
- Relatively stable behaviour over time for the FQI solution
- CN-based approach tends to exhibit instability/frequent state changes

Summary & conclusions

- FQI scheme extends QoS model and offers flexibility in defining desired behaviour in different congestion levels
- We provided a methodology how to evaluate congestion management schemes in mobile networks
- We illustrated the difference between the FQI solution and a CN-based approach with packet-level simulations
  - FQI based solution keeps the system in lower congestion level -> better user experience during congestion
  - FQI based solution can follow a wide range of operator targets

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