MOBILE VCE

KING'S College LONDON

University of London

Cross-Layer Optimisation to Maximise Fairness among TCP flows of different TCP flavors.

Toktam Mahmoodi
King's College London,
London, UK

IEEE GLOBECOM
30Nov-4Dec 2008, New Orleans

Presentation Structure

- Introduce the challenges and locate this research.
- TCP flavors and Packet Losses
  - **Throughput Comparison**
- Definition of Fairness
- Jain's Index as a notion of Fairness
- Improving Fairness among TCP flows
  - **Fairness Maximization Problem**
  - **Real-time solution**
- Performance Investigation
  - **Significant increase in Fairness**
  - **Minimal effect on the aggregated throughput of TCP**
- Conclusions

Introduce the challenges

- In wired networks, end-to-end data transmission relies on the functionalities of the Transport Layer, i.e., TCP, for congestion control, fairness, loss recovery, etc.
- *Random* and *Time-variant* characteristics of wireless links fool TCP algorithms.
- A vast amount of research has been conducted in order to introduce enhancements in the Transport Layer to perform better in the wireless networks.
- A common approach is to increase the intelligence of wireless links to be aware of TCP.

Locate this Research

- We expand the cross-layer algorithms from the traditional Layer 1 and 2 interactions, up to the Transport Layer.
- As we aim to support higher data rates, Transport layer performance plays an extremely important role.
- Our research does not attempt to propose any new technique to the Transport Layer.
- We aim to:
  - **improve the end-to-end performance, which is all that can be actually seen from user's perspective.**
  - **rely on the well-used Transport Layer over Internet, TCP, for data transmission.**
  - **study a scenario that different TCP flavors competing over the wireless network.**

TCP Flavors and Packet losses

- In the absence of losses TCP congestion control behavior is similar in most TCP flavors; per RTT *cwnd* increases.

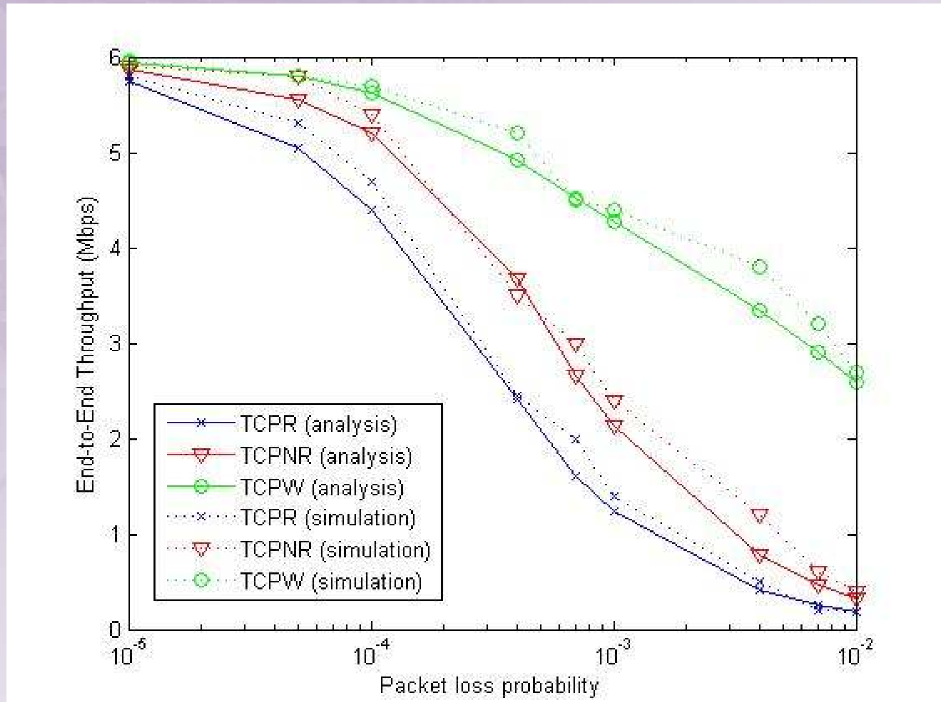
  - **Exponential Initially: slow-start phase**
  - **Linear afterward: congestion control phase**

- In the presence of losses, different TCP flavors react differently to the loss.
- TCP Throughput models, which captures this effect, are used from the literature [1], [2], and [3] for the Reno, NewReno and westwood TCP.

IEEE GLOBECOM
30Nov-4Dec 2008
New Orleans

Throughput Comparison

- Single-flow Scenario of TCP Reno, TCP NewReno, TCP westwood and SACK option.



- ✓6Mbps bottleneck link.
- ✓RTT = 100ms.
- ✓ FTP download a file of ~11,000 packets
- ✓TCP packet size is 1460B.

- TCPR degrades most dramatically in the event of losses.
- models and the analyses perform almost identically.

CENTER for TELECOMMUNICATIONS RESEARCH

KING'S College LONDON
University of London

MOBILE VCE

www.mobilevce.com

Jain's Fairness Index

- Jain's Index introduced to measure fairness in computer networks in 1984 [5].

$$J = \frac{\left(\sum_{i=1}^{n} x(p_i)\right)^2}{n.\sum_{i=1}^{n} x(p_i)^2}$$

✓ ***J* is independent of the scale of allocation metric (*x*).**

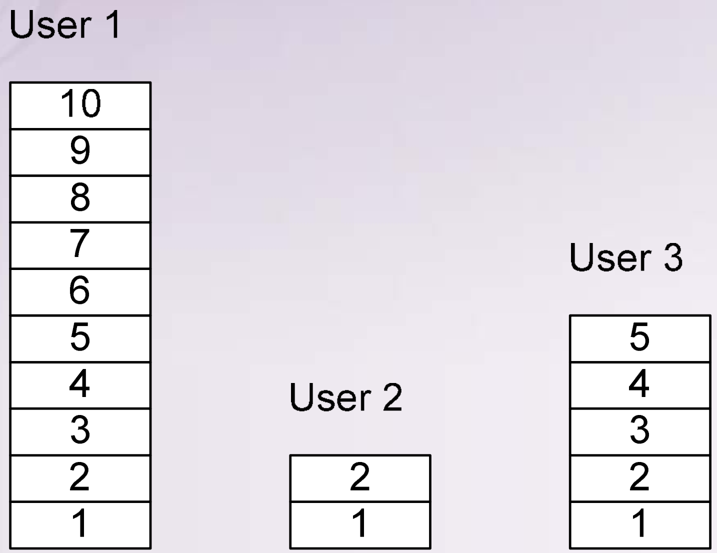
✓ ***J* is bounded between 0 and 1.**

✓ **1 is completely fair and 0 is completely unfair allocation.**

- Assuming allocated rate for user *i*, operating in PER p_i, is $r(p_i)$ where the optimal rate for user *i* is R_i, then $x(p_i)= r(p_i)/R_i$.
- *n* is the number of flows in the network.

Fairness Definition

- In the literature, *Fairness* is defined as Equality.
- We define *Fairness* as Equal access to the resources proportional to the potential of each user to utilize that resources.
- For example, if users' capacity is defined by their buffer size, then the fair allocation would be to allocate more to the user with the larger buffer.



✓Total available data is 9B.

✓Equal assignment results in Jain index = 0.7.

✓Assigning proportional to the users' capacity (5B to U1, 1B to U2, and 3B to U3) results in Jain index =0.99.

Fairness Maximisation

- The aim is to maximise fairness among TCP flows.

$$(\mathrm{P}): \quad \text{maximise } J(p) = \frac{\left(\sum_{i=1}^{n} x(p_i)\right)^2}{n \cdot \sum_{i=1}^{n} x(p_i)^2},$$

$$\sum_{i=1}^{n} B_k(p_i) \le W, \quad \forall k \in \{1..4\}$$

$$p_i \cdot 10^{-e} \le p_i \le p_i \cdot 10^{e}, \quad \forall i \in \{1..n\}$$

$$p_i \ge 0, \quad \forall i \in \{1..n\}$$

✓**Link Capacity is limited to *W*.**

✓**Exponent of PER can vary in the close interval of [*p*-*e*,*p*+*e*].**

✓PER can be seen by flow *i* is p_i ; thus flow *i* of TCP flavor *k* can achieve throughput of $B_k(p_i)$.

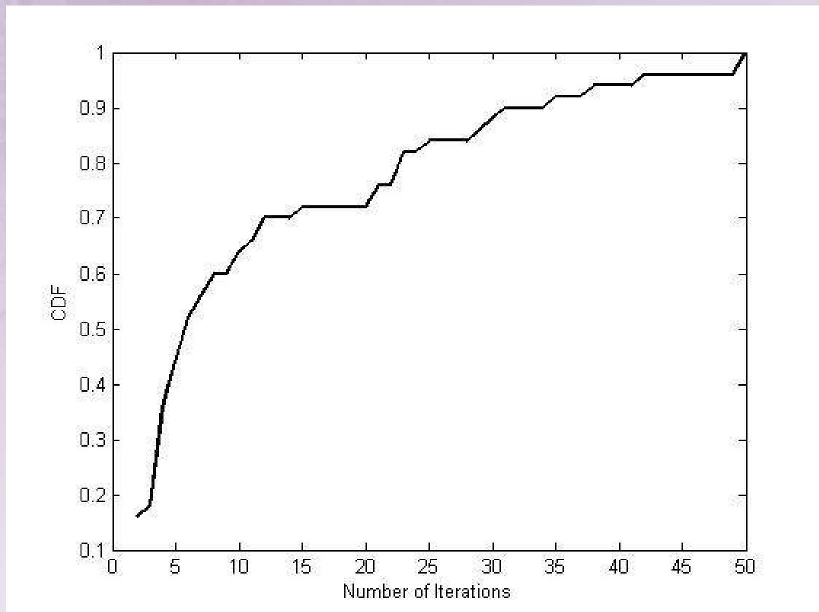
✓Throughput expressions of the four used TCPs are from [2-5]

✓Optimal throughput for flow *i* is achieved when all the other *n-1* users have the same TCP flavor.

$$x(p_i) = \frac{B_k(p_i)}{B_{k_{Optimal}}},$$

Heuristic Solution

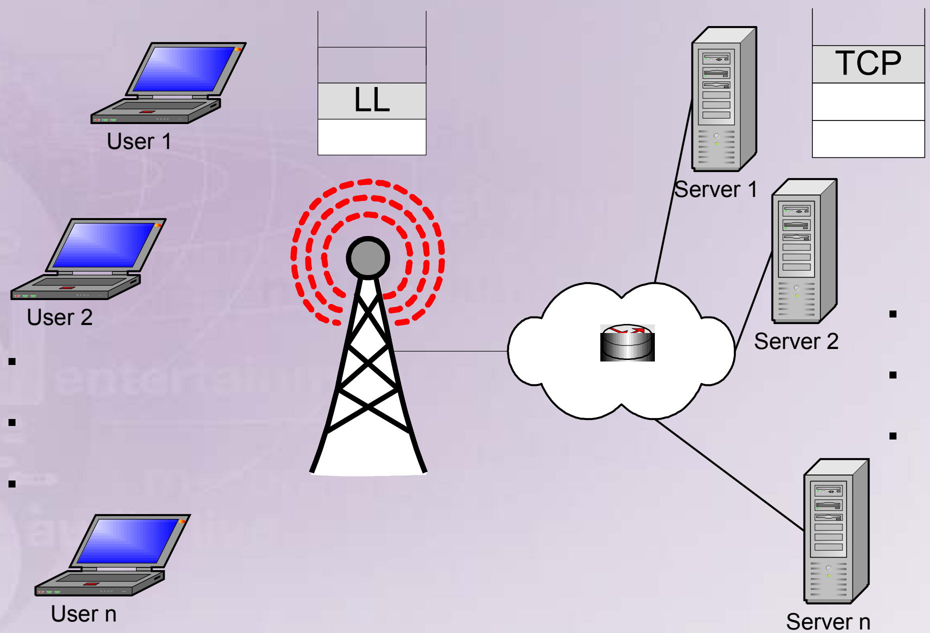
- The problem is approximated, to be solved it in *real time*. The approximated problem is solved using *Newton method*.
- We show that the solution converges to the optimal value in few number of iterations.



CDF of the number of iterations required in solving the problem.

✓**Maximum 50 iterations are used.**
✓**Average number of required iterations is 12.**
✓**In 70% of cases, the optimal value is attained in less than 15 iterations.**

Network Configuration



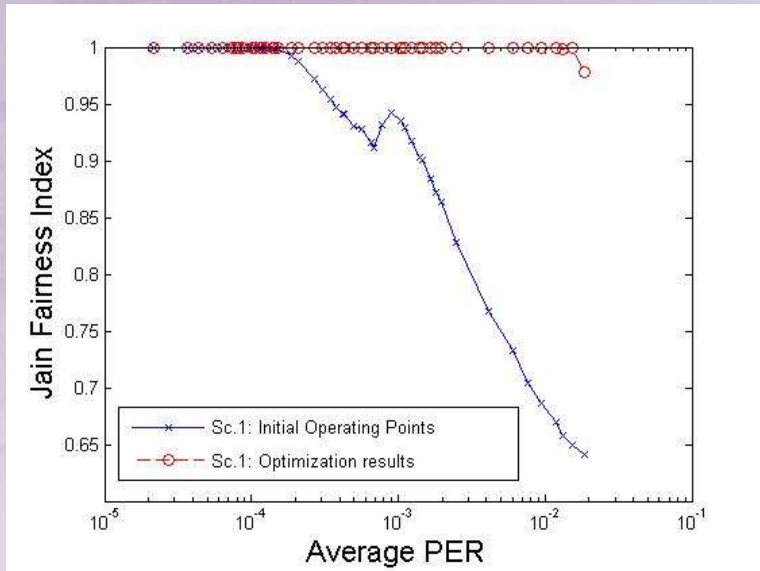
Using the information of the Transport layer, optimisation performs in the wireless AP.

- ✓IEEE 802.11a.
- ✓Max data rate of 54 Mbps.
- ✓15 mobile users.
- ✓15 FTP servers.
- ✓Each client is connected to a unique server.
- ✓All traffic flows are served by the single wireless AP.
- ✓TCP flows are of different combinations of the three TCP flavors.

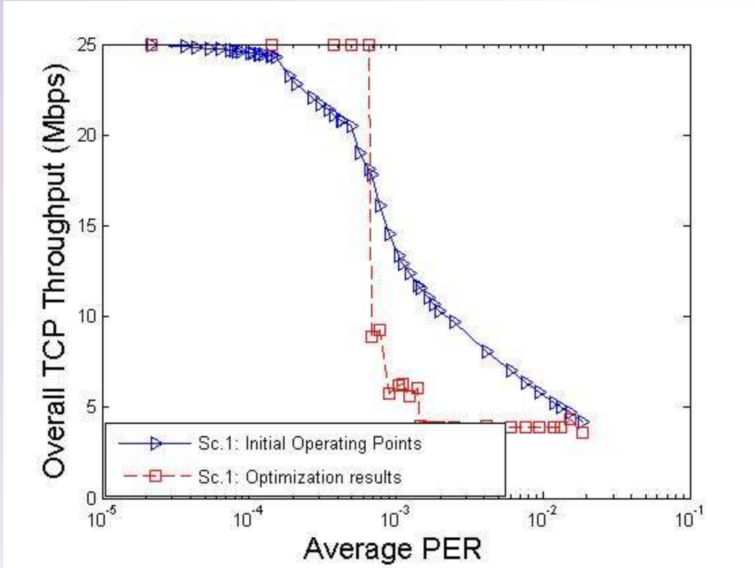
IEEE GLOBECOM
30Nov-4Dec 2008
New Orleans

Numerical Results: Scenario 1

- Of the 15 TCP flows, there are five TCPR, five TCPNR, five TCPW.



The fairness index versus average PER: Significant increase of up to 50% in the high error rate conditions is observed.



TCP throughput versus average PER: Slight decrease in the high error rate and slight increased in the low error rate is observed.

CENTER for TELECOMMUNICATIONS RESEARCH

KING'S College LONDON

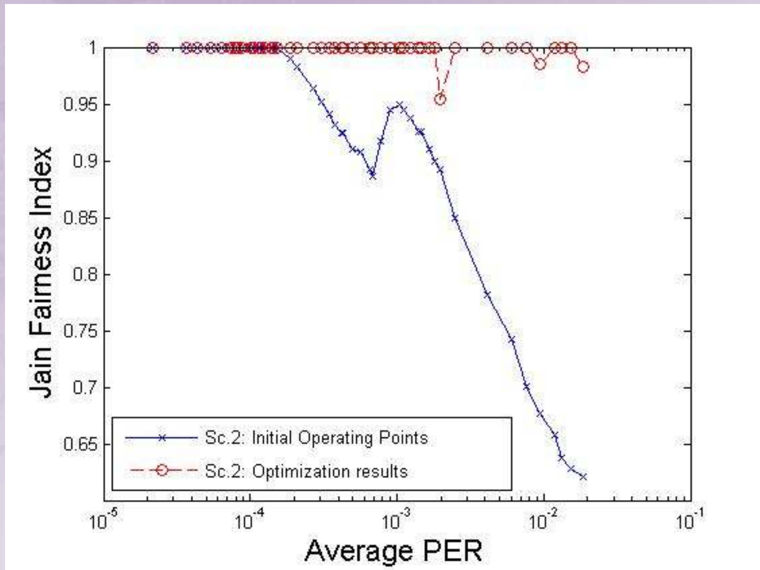
University of London

MOBILE VCE

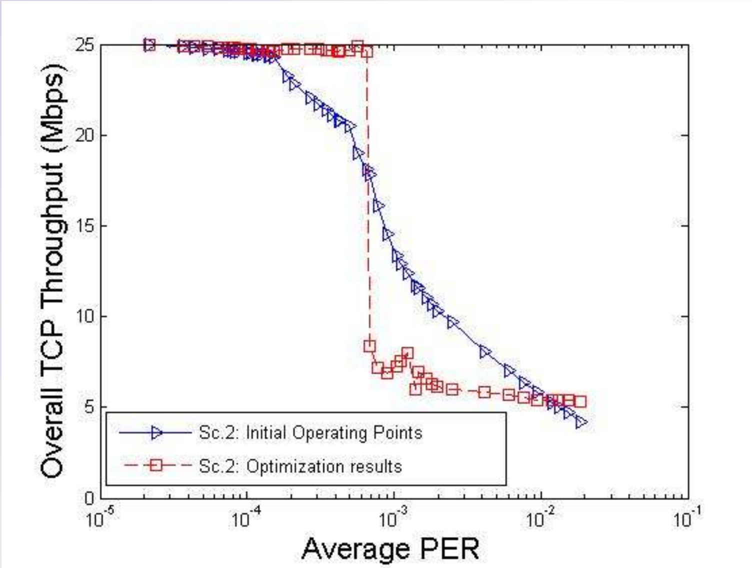
www.mobilevce.com

Numerical Results: Scenario 2

- Of the 15 TCP flows, there are nine TCPR, four TCPNR, two TCPW.



The fairness index versus average PER: Observation is similar to Scenario 1.



TCP throughput versus average PER: Observation is similar to Scenario 1.

CENTER for TELECOMMUNICATIONS RESEARCH

KING'S College LONDON

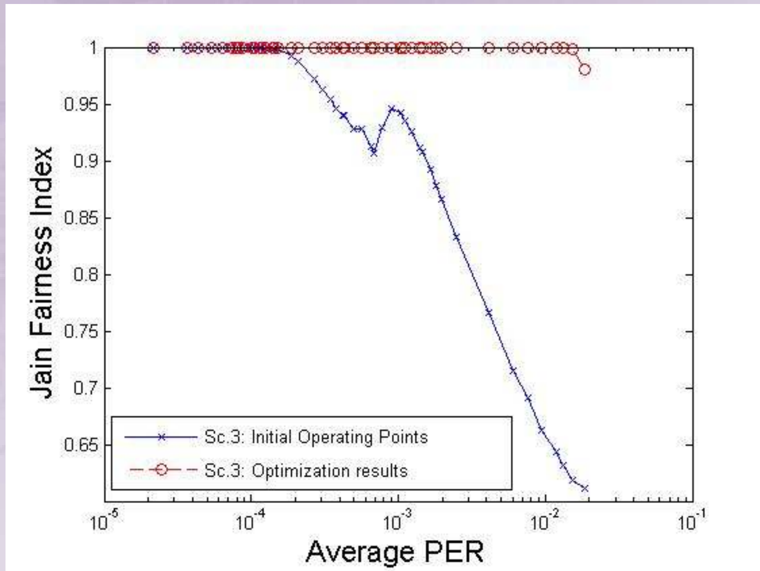
University of London

MOBILE VCE

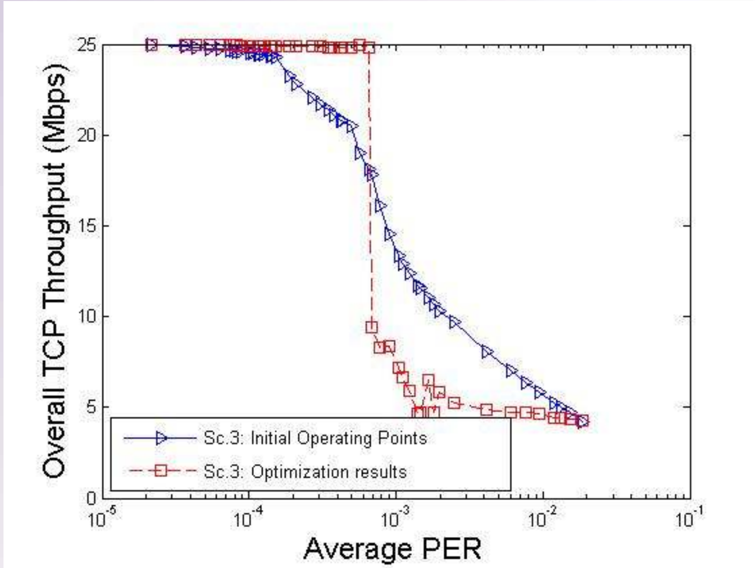
www.mobilevce.com

Numerical Results: Scenario 3

- Of the 15 TCP flows, there are three TCPR, eight TCPNR, four TCPW.



The fairness index versus average PER: Observation is similar to Scenario 1.



TCP throughput versus average PER: Observation is similar to Scenario 1.

Conclusions

- We have studied scenarios where multiple TCP flows are from different TCP flavors.
- The unfairness among TCP flows arises from different reaction to packet loss of each TCP flavor.
- The FEC code rate is adopted not only to achieve higher reliability on the wireless link, but also to consider the theoretical bands apply by the TCP flavor in use.
- Our approach doesn't attempt to change the TCP.
- The overall results show up to 50% improvement in the fairness index with no significant effect on the overall end-to-end throughput.

References

[1] J. Padhye, V. Firoiu, D. F. Towsley, and J. F. Kurose, “Modeling TCP Reno Performance: A Simple Model and Its Empirical Validation,” IEEE/ACM Tran. Net., vol. 8, pp. 133–145, Apr. 2000.

[2] B. Sikdar, S. Kalyanaraman, and K. S. Vastola, “Analytic Models for the Latency and Steady-State Throughput of TCP Tahoe, Reno, and SACK,” IEEE ACM Tran. Net., vol. 11, pp. 959–971, Dec. 2003.

[3] R. Dunaytsev, Y. Koucheryavy, and J. Harju, “TCP NewReno Throughput in the Presence of Correlated Losses: The Slow-but-Steady Variant,” Proc. IEEE INFOCOM’06, pp. 115–120, Spain, Apr. 2006.

[4] A. Zanella, G. Procissi, M. Gerla, and M. Y. Sanadidi, “TCP Westwood: Analytic Model and Performance Evaluation,” Proc. IEEE GLOBECOM’01, vol. 3, pp. 1703–1707, Texas, Dec. 2001.

[5] R. Jain, D. Chiu, and W. Hawe, “A Quantitative Measure Of Fairness And Discrimination For Resource Allocation In Shared Computer Systems,” DEC Research Report TR-301, Sep. 1984.

CENTER for TELECOMMUNICATIONS RESEARCH

KING'S College LONDON

University of London

MOBILE VCE

Thanks for your attention!

For further information please contact:

toktam.mahmoodi@kcl.ac.uk