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A. Jain
A. Terzis
Google
N. Sprecher
S. Arunachalam
Nokia Networks
K. Smith
G. Klas
Vodafone
March 13, 2017

**Requirements and reference architecture for Mobile Throughput Guidance
Exposure
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Abstract

Rapidly-varying conditions in a cellular network can cause problems for the Transmission Control Protocol (TCP), which in turn can degrade application performance.

This document presents the problem statement and proposes solution principles. It specifies the requirements and reference architecture for a mobile throughput guidance exposure mechanism that can be used to assist TCP in cellular networks, ensuring better network efficiency and enhanced service delivery performance.

The proposed mechanism can be applied to any content or TCP/IP based application content delivery. This document describes the applicability of the mechanism for Intelligent Video Acceleration over cellular networks.

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[1. Introduction](#)

Mobile-edge Computing provides IT and cloud-computing capabilities within the Radio Access Network in close proximity to mobile subscribers [[MEC White Paper](#)]. Mobile Throughput Guidance is an solution building on top of MEC concepts to improve customer experience during mobile Internet sessions, by making explicit what

range of bandwidth the mobile access link is likely to sustain [[MTG GSMA White paper](#)].

The following sub-sections present the problem statement and the solution principles for Mobile Throughput Guidance.

1.1. Contributing Authors

The editors gratefully acknowledge the following additional contributors: Hannu Flinck, Helen Parsons, Peter Cosimini and Ram Gopal.

1.2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

1.3. Acronyms and Abbreviations

HTTP	Hypertext Transmission Protocol
IP	Internet Protocol
LTE	Long Term Evolution
RAN	Radio Access Network
RTT	Round Trip Time
TCP	Transmission Control Protocol
UE	User Equipment

1.4. Problem statement

Inefficient use of a cellular network's resources degrades application performance, delivery of content and user experience.

Cellular networks are often required to deliver large, high bandwidth files to end users, e.g from streaming media content providers. If the available throughput from the Radio Access Network (RAN) to the User Equipment (UE) falls below the bandwidth required then files are delivered too slowly, resulting in a bad user experience. It may be possible to take avoiding action and so limit the impact on the network and the user experience. However to be able to do this in an accurate and timely fashion, information on the available throughput is required.

Internet media and file delivery are typically streamed or downloaded today using Hypertext Transmission Protocol (HTTP) over the TCP. The behavior of TCP assumes that network congestion is the primary cause for packet loss and high delay. This may not be the case in cellular networks where the bandwidth available for each UE can vary by an

order of magnitude within a few seconds due to changes in the underlying radio channel conditions. Such changes can be caused by the movement of devices or interference, as well as changes in system load due to bursty traffic sources or when other devices enter and leave the network. On the other hand, packet losses tend to be sporadic and temporary; retransmission mechanisms at the physical and link layers repair most packet corruptions.

1.5. Solution Principles

This document proposes that the cellular network could provide near real-time information on "Throughput Guidance" to the TCP server; this throughput guidance information would indicate the throughput estimated to be available at the radio downlink interface (between the RAN and the UE) for the TCP connection.

While the implementation details will vary according to the cellular access network technology, the resource allocation can be abstracted as the capacity of the "radio link" between the network and the UE. For example, in the case of an LTE network, the number of physical resource blocks allocated to a UE, along with the modulation scheme and coding rate used, can be translated into radio link capacity in Megabits per second (Mbps). It can also include the quality of the "radio link" which is reported by the UE.

The TCP server can use this explicit information to inform several congestion control decisions. For example: (1) selecting the initial window size, (2) deciding the value of the congestion window during the congestion avoidance phase, and (3) reducing the size of the congestion window when the conditions on the "radio link" deteriorate. In other words, with this additional information, TCP does neither have to congest the network when probing for available resource, nor rely on heuristics to reduce its sending rate after a congestion episode.

The same explicit information can also be used to optimize application behavior given the available resources. For example, when video is encoded in multiple bitrates, the application server can select the appropriate encoding for the network conditions.

Note that the throughput estimation for the upstream traffic between the UE and the RAN, and the throughput of the network path between the RAN and the server communicating with the UE are beyond the scope of the document.

It is also important to note that the validity of the throughput guidance and the distance between the originating server and the cellular network (in terms of the number of Internet hops) are

inversely proportional. This is due to the fact that the latency incurred at each hop increases the time that elapses between issuing and consuming the guidance.

2. Requirements

The requirements set out in [section 2.1](#) are for the behavior of the mobile throughput guidance exposure mechanism and the related functional elements. The related security requirements are specified in [section 2.2](#).

2.1. Requirements on the Mobile Throughput Guidance Exposure Mechanism

1. The throughput guidance information SHALL indicate the expected available bandwidth in the downlink interface. Depending on the solution mechanism, the information MAY be provided per TCP flow or per user. If the solution mechanism supports both options, then granularity SHOULD be configurable.
2. The throughput guidance information SHALL be provided for TCP based traffic.
3. A functional element, residing in the RAN and acting as Throughput Guidance Provider, SHOULD supply the TCP server a near real-time indication (in sub-seconds) on the throughput estimated to be available at the radio downlink interface (i.e., mobile throughput guidance information). It SHOULD keep up with the rapid changes in the radio network conditions, the network traffic and the user movement, in order to provide the most accurate guidance information. Throughput Guidance Provider SHALL access to Network Radio Information.
4. The introduction of the Throughput Guidance exposure mechanism SHALL NOT require any update to the TCP client software.
5. The mobile throughput guidance exposure mechanism SHALL work when the user traffic is end-to-end encrypted (e.g., HTTPS, etc.). This requirement is compliant with the IAB Statement on Internet Confidentiality (see [[IAB Statement](#)]), saying that the IAB "strongly encourage developers to include encryption in their implementations, and to make them encrypted by default. We similarly encourage network and service operators to deploy encryption where it is not yet deployed, and we urge firewall policy administrators to permit encrypted traffic."
6. The mobile throughput guidance exposure mechanism SHALL NOT adversely impact the behavior of the TCP flows (e.g., it SHOULD

NOT cause an increase in retransmissions or degradation in performance, etc.).

7. The mobile throughput guidance exposure mechanism SHALL ensuring end-to-end consistency of the TCP flow control. The throughput guidance information SHALL NOT override the TCP flow window limits (e.g. $\min(\text{cwnd}, \text{rwnd})$) or timer values.
8. The throughput guidance information SHALL be opaque to the intermediate elements between the Throughput Guidance Provider and the TCP server. The intermediate elements SHOULD NOT modify or remove the throughput guidance information.
9. The TCP server MAY reside within the mobile operator's network (behind the mobile core network) or in the Internet.
10. The TCP server MAY use the mobile throughput guidance information to assist TCP.
11. It SHOULD be possible for the TCP server to provide the exposed mobile throughput guidance information to an authorized higher layer application. The application may use the mobile throughput guidance information to optimize its behavior.
12. The Throughput Guidance Provider SHOULD provide the mobile throughput guidance information periodically, starting from the initiation of the flow.
13. The frequency (in milliseconds) at which mobile throughput guidance needs to be exposed SHALL be configurable.
14. The mobile Throughput Guidance Provider SHALL be able to supply mobile throughput guidance information to more than one TCP server simultaneously, with independent configurable parameters for each server.
15. There SHOULD be a mechanism to configure the Mobile Throughput Guidance Provider with a list of TCP flows for which mobile throughput guidance information shall be exposed.
16. The mobile throughput guidance exposure mechanism SHOULD ensure backward compatibility. Normal TCP processing at the TCP server SHOULD be performed if the TCP server does not recognize the throughput guidance information.
17. The mobile throughput guidance exposure mechanism MUST be extensible, ensuring that additional information can be provided in the future in a non-disruptive, backward-compatible way.

2.2. Security requirements

1. A trustful relationship between the Mobile Throughput Provider and the TCP server SHOULD be formed before any information is exposed.
2. There SHOULD be a mechanism to configure the Mobile Throughput Guidance Provider with a list of destinations to which throughput guidance should be provided.
3. The identity of the Mobile Throughput Guidance Provider SHALL be explicitly known to the TCP server which receives the information. The TCP server SHALL be able to authenticate the identity of the Mobile Throughput Guidance Provider. The Mobile Throughput Guidance Provider MUST NOT reveal any other identity or address of network elements that can compromise the security of the network.
4. The mobile throughput guidance information SHOULD be secured to ensure confidentiality and integrity.
5. There SHOULD be a mechanism to configure the required security level and parameters for the encryption and the authentication if supported.
6. The exposure of the Mobile throughput guidance information SHALL NOT introduce any additional security threats and privacy concerns to the mobile operator's network, the Internet and the users.
7. The throughput guidance SHOULD be treated only as an estimate to the optimization algorithm running at the TCP server. The TCP server that receives this information SHOULD NOT assume that it is always accurate and up to date. Specifically, the TCP server SHOULD check the validity of the information received and if it finds it erroneous it SHOULD discard it and possibly take other corrective actions (e.g., discard all future throughput guidance information from a particular IP prefix).

3. Reference Architecture

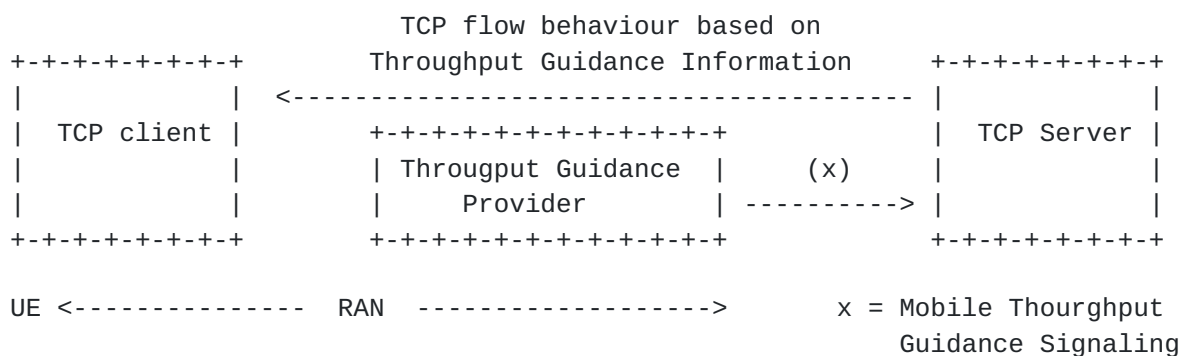
Figure 1 below, depicts the functional elements and their interfaces that comprise the mobile network guidance solution (based on the requirements for mobile throughput guidance).

A Throughput Guidance Provider functional element signals to the TCP server the information on the (near-real time) throughput estimated

to be available at the radio downlink interface. The TCP server resides within the mobile operator's network or in the Internet.

Note that the Throughput Guidance Provider functional element and the TCP server can belong to the same Administrative System (AS) or to different Administrative Systems.

The TCP server MAY use the information to optimize the TCP behavior. The information MAY also be used by the application to adapt its behavior accordingly and to optimize service delivery performance.



Mobile Throughput Guidance Reference Architecture

Figure 1

The information source and the algorithm used by the Throughput Guidance Provider to calculate the throughput guidance are beyond the scope of this document.

The TCP server MAY use the throughput guidance information to assist TCP in any of the following ways:

- o Determine the size of the initial congestion window
- o Determine when to exit the slow start phase
- o Determine the size of the congestion window during the congestion avoidance phase
- o Determine the size of the window after a congestion event

4. Applicability to Mobile Video Delivery Optimization

The mobile throughput guidance exposure mechanism applies to mobile video delivery optimization.

In this use case the Throughput Guidance Provider sends to the video server throughput guidance information for a TCP flow. The video server may use this information to assist TCP congestion control decisions, for example in selecting the initial congestion window size, and adjusting the size of the congestion window when the conditions on the radio link change. In other words, with this additional information, TCP does not need to overload the network when probing for available resources, nor does it need to rely on heuristics to reduce its sending rate after a congestion episode. Slow start and buffering of content delivery can be eliminated.

The same information may also be used to ensure that the application level coding matches the estimated capacity at the radio downlink.

The aim of all of these improvements is to enhance the end user's quality of experience. For example, the content's time-to-start as well as video buffering occurrences can be reduced, the utilization of the radio network's resources and its throughput can be optimized, etc.

5. Manageability considerations

Manageability of mobile throughput guidance exposure will be discussed in the solution documents. [Section 2](#) specifies a set of requirements on the management of the mobile throughput guidance exposure functional elements and protocol operation.

6. Security considerations

The exposure of mobile throughput guidance information from the cellular network to the TCP server introduces a set of security considerations.

As per requirement #3 in [section 2.2](#), the TCP server SHALL be able to authenticate the identity of the Mobile Throughput Guidance Provider. The Mobile Throughput Guidance Provider MUST NOT reveal any other identity or address of network elements that can compromise the security of the network.

Furthermore, the throughput guidance information should be treated only as an estimate to the congestion control algorithm running at the transport endpoint. The endpoint that receives this information should not assume that it is always correct and accurate.

Specifically, endpoints should check the authenticity and integrity of the information received and if they find it erroneous they should discard it and possibly take other corrective actions (e.g., discard all future throughput guidance information from a particular IP prefix).

One way to check if the throughput guidance information overestimates the capacity available on the radio link is to check whether any packet losses or other signs of congestion (e.g., increasing RTT) occur after the guidance is used. Notably, the same mechanism can be used to deal with bottlenecks in other parts of the end-to-end network path. To check if the throughput guidance underestimates the available network capacity, the source can periodically attempt to send faster and then check for signs of congestion.

[Section 2](#) above, specifies a set of requirements on the mobile throughput guidance exposure protocol to ensure secured communication and operation.

7. IANA considerations

This requirements and architecture document does not introduce any requests for IANA actions.

8. Acknowledgements

We would like to thank Peter Szilagyi, Meir Cohen and Csaba Vulkan for conversations on these issues.

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Authors' Addresses

Ankur Jain
Google
1600 Amphitheatre Parkway
Mountain View, CA 94043
US

Phone: +1-925-526-5879
Email: jankur@google.com

Andreas Terzis
Google
1600 Amphitheatre Parkway
Mountain View, CA 94043
US

Phone: +1-650-214-5270
Email: aterzis@google.com

Nurit Sprecher
Nokia Networks
Hod HaSharon
IL

Phone: +97297751229
Email: nurit.sprecher@nsn.com

Swaminathan Arunachalam
Nokia Networks
Irving
FUS

Phone: +19723303204
Email: swaminathan.arunachalam@nsn.com

Kevin Smith
Vodafone
One Kingdom Street, Paddington Central
London W2 6BY
UK

Email: kevin.smith@vodafone.com

Guenter Klas
Vodafone
One Kingdom Street, Paddington Central
Newbury RG14 2FN
UK

Email: kguenter.klas@vodafone.com