Integration of PLMN and Satellite Networks for Train Control and Traffic Management via MPTCP

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Outline

- Introduction
- Motivation
- Introduction of MPTCP
- Approach Architecture
- Experiment results
- Conclusion

Introduction

- Scope:
  - propose a new architecture based on the integration of best effort PLMNs and QoS guaranteed satellite networks, that makes use of MultiPath Transmission Control Protocol.
  - Focus on the logic for dynamically adding, dropping and assigning priority to the paths corresponding to the QoS guaranteed and best effort networks.

- Experiment design:
  - City scenario
  - Harsh environment

- Test Bed:
  - Machine-to-Machine (M2M) emulator.

Motivation

- ERTMS/ETCS is the most advanced standard for managing and controlling of railway traffic and GSM-R communication subsystem, based on GSM technology, is one of its main components.

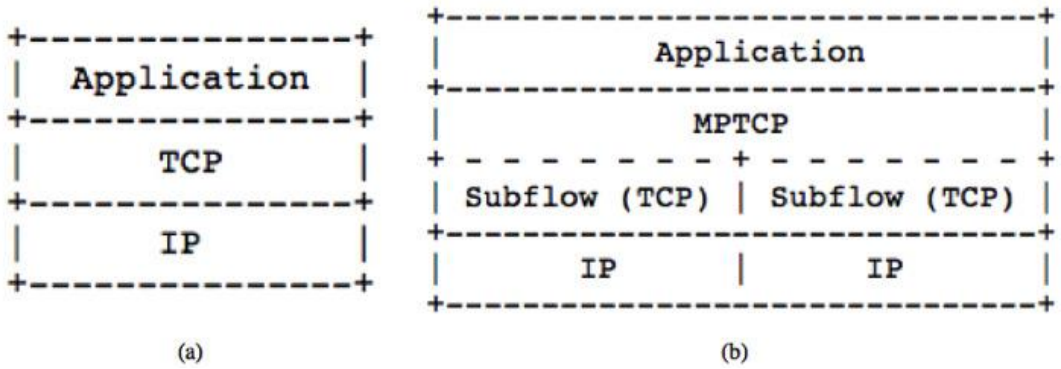
- GSM-R is no longer able to effectively support current and further developments of services for ERTMS/ETCS.
  - It has reached the technological limits and comes out some shortcomings
    - Technological obsolescence
    - Adjacent channels interference
    - Limitation of transmission capacity
  - GSM-R is a dedicated communication system, which requires large economic investments to operate.

- There is a crucial demand of new communication systems
    - Lower costs
    - Increased service capacity,
    - Complementing GSM-R in the short/medium term, and replacing it in future.

- The design of architectures integrating state of the art communication technologies into railway control/management is a challenging task

Introduction of MPTCP

- MPTCP is a set of extension protocols to regular TCP, which provides a Multipath TCP service, enabling a transport connection via multiple paths simultaneously.
- Use of MPTCP does not require modifications at application layer.
- MPTCP adds the additional MPTCP layer between the application and TCP layers.

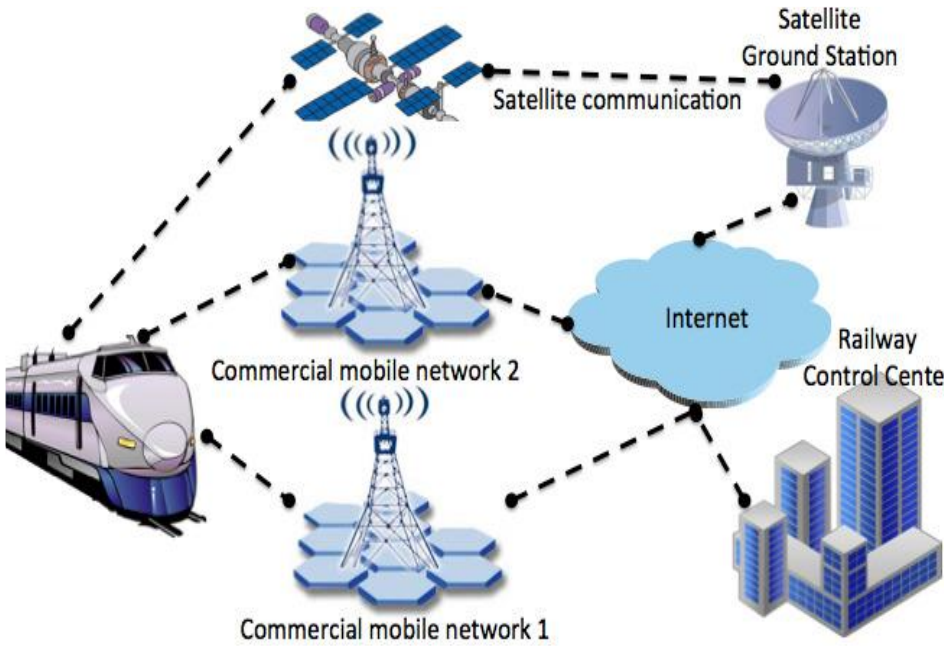


- MPTCP can provide a deep integration over existing technologies as 2G, 3G, LTE, WiMAX, WiFi and Satellite networks with few investment and modifications.

Architecture

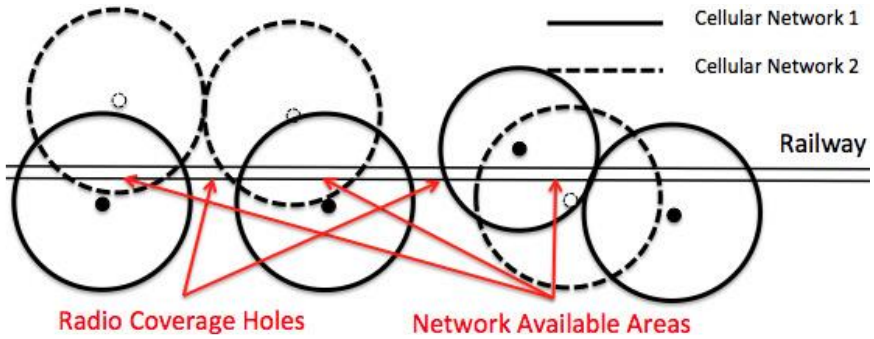
- The QoS link is provided by the satellite network
- The best effort links are provided by PLMNs operated by diverse operators
- On board network accessing equipment and control center network equipment should be multipath aware.
- On board terminals are equipped at least two kind of network access devices corresponding to the employed radio technologies

(PLMN & Satellite)



Outage percentage estimation

- Along railways,areas where not served by any PLMN or the QoS required for successful train control is not reached for the majority of the time, denoted as PLMN radio coverage holes.



- The overlap percentage L is defined as

$$L = \frac{\sum_{i=1}^{N_l} l_i}{T_{tot}}$$

- l_i is the time interval for the train to cross the i^{th} area, served by two PLMNs
- T_{tot} is the total time of the travel
- N_l is the number of overlap areas

- The outage percentage P_{out} can be expressed

$$P_{out} = \frac{\sum_{i=1}^{N_Q} Q_i}{T_{tot}}$$

- Q_i is the time interval required for the train to cross the i^{th} radio holes
- T_{tot} is the overall of the travel
- N_Q is the number of radio holes

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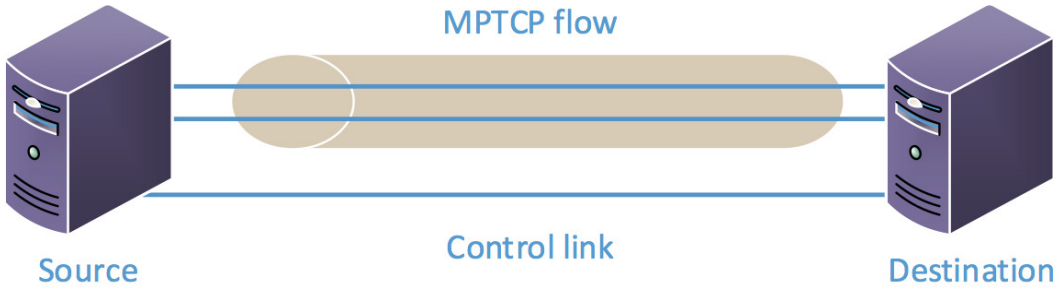
Test bed

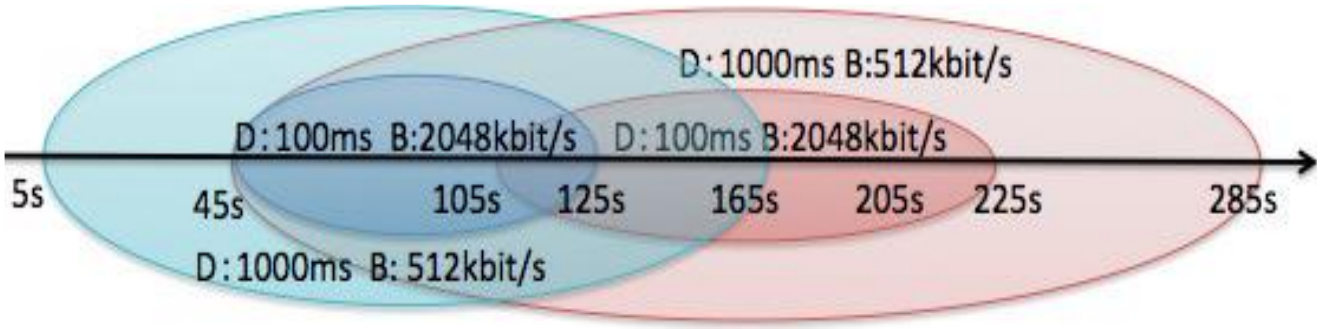
- Two virtual machines with Ubuntu 14.04 32bit operation systems are installed in VirtualBox.
- In each virtual machine, a Mutilpath TCP capable Linux Kernel (version 3.16) is loaded.
- Every virtual machine is configured with three network adapters:
  - Two network adapters simulate the best effort and the QoS guaranteed path
  - One adapter is used to synchronize the time by means of NTP



- The traffic was generated by D-ITG (Distributed Internet Traffic Generator)].
- Both inbound and outbound traffic was monitored and recorded through Wireshark.

City scenario

- The blue circles denote the regions covered by a PLMN
  - The inner circle corresponding to the area near the base station, has a nominal delay of 100 ms and a throughput of 2048 kbit/s
  - The outer ring has a nominal delay of 1000 ms and a throughput of 512 kbit/s
- The red circles denotes a second PLMN with the same features as the blue ones
- Transmission packet flow with bitrate of 400 kbit/s, handled by a round robin scheduler



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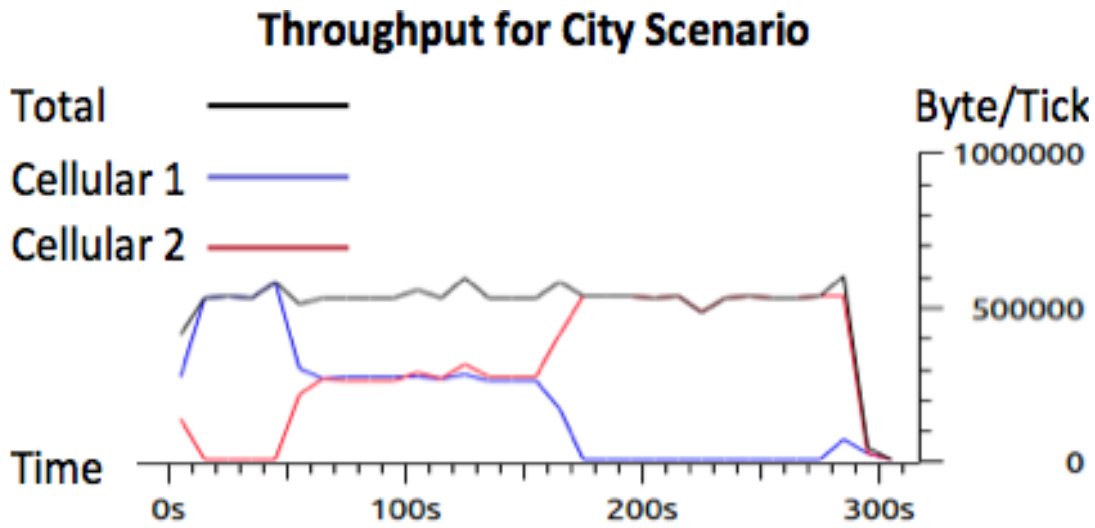
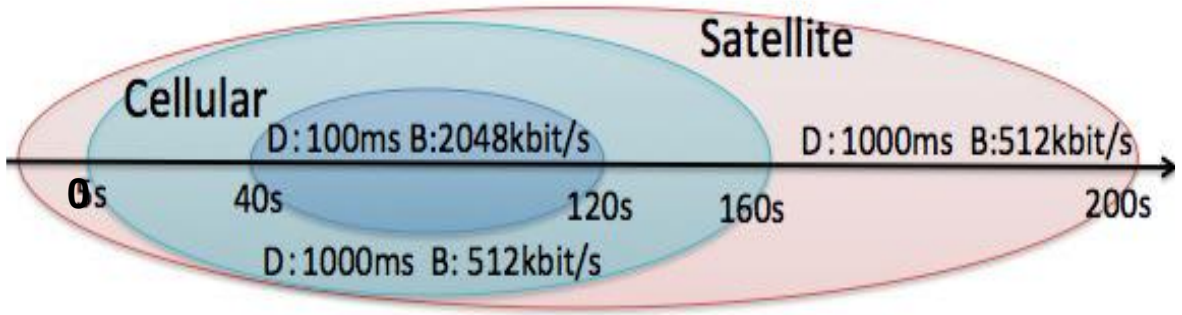
Test result for city scenario

1. All the payload are transmitted over one network depict in blue
2. The other network becomes available drawn in red
3. Payload is split on both networks.
4. The networks represented in blue becomes unavailable
5. All payload is routed to the red one.
6. The total throughput corresponding to the black line, remains stably during the entire transmission period.



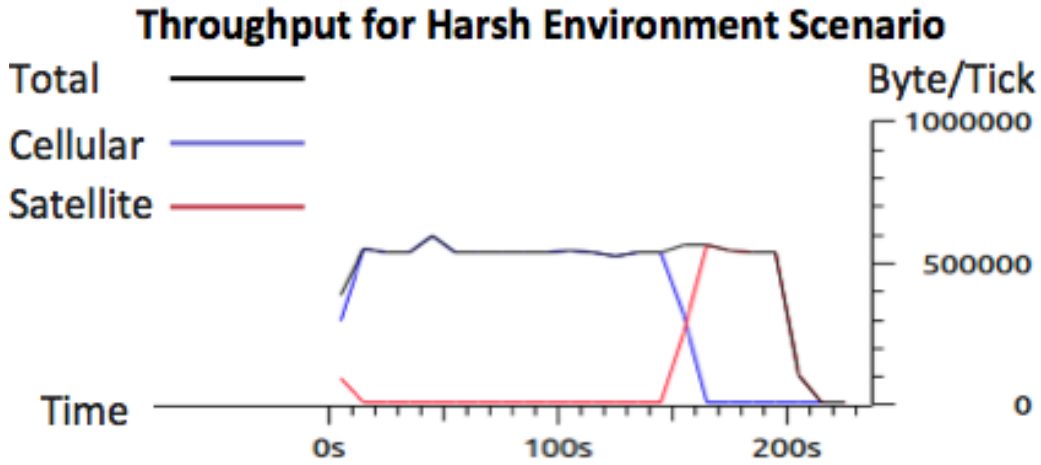
Harsh environment scenario

- The blue circles denote the regions covered by a PLMN
  - The inner circle corresponding to the area near the base station, has a nominal delay of 100 ms and a throughput of 2048 kbit/s
  - The outer ring has a nominal delay of 1000 ms and a throughput of 512 kbit/s
- The red circle represents the area covered by the satellite network
  - It features a 1000 ms nominal delay and a 512 kbit/s throughput
- Transmission packet flow with bitrate of 400 kbit/s, handled by a round robin scheduler



Test result for harsh environment scenario

1. All the payload are transmitted over one network depict in blue
2. The network drawn in blue becomes unavailable
3. Open the satellite network interface
4. All payload is routed to the red one
5. The total throughput corresponding to the black line, remains stably during the entire transmission period.



Conclution

- We proposed a new communication system architecture as an alternative solution of GSM-R to support the train control/management system.
- The communication can be executed over multiple best effort and QoS guaranteed networks simultaneously by using MPTCP.
- Proper setting of MPTCP add and drop subflow logic as well as MPTCP priority allows the implementation of a seamless vertical handover procedure.

End

Thank You !

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