TrainNet: a novel transport infrastructure for non real-time data delivery

Mohammad Zarafshan Araki

University of Wollongong

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TrainNet: A Novel Transport Infrastructure for Non Real-Time Data Delivery

A thesis submitted in fulfilment of the requirements for the award of the degree

Master of Engineering (Research)

from

THE UNIVERSITY OF WOLLONGONG

by

Mohammad ZARAFSHAN ARAKI
Master of Internet Technology (with Distinction)

SCHOOL OF ELECTRICAL, COMPUTER AND TELECOMMUNICATIONS ENGINEERING

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Abstract

To date, researchers have proposed many vehicular networks in which cars or buses act as a mechanical backhaul for transporting data. For example, a bus can be retrofitted with a computer and wireless card to automatically ferry data to/from rural villages without Internet connectivity. Alternatively, a person carrying a portable storage device can be used to link geographically disparate networks. These examples of challenged networks are characterized by frequent disruptions, long delays, and/or intermittent connectivity.

This thesis proposes TrainNet, a vehicular network that uses trains to transport latency insensitive data. TrainNet augments a railway network by equipping stations and trains with mass storage devices; e.g., a rack of portable hard disks. TrainNet has two applications. First, it provides a low cost, very high bandwidth link that can be used to deliver non real-time data. In particular, cable TV operators can use TrainNet to meet the high bandwidth requirement associated with Video on Demand (VoD) services. Moreover, TrainNet is able to meet this requirement easily because its links are scalable, meaning their capacity can be increased inexpensively due to the continual fall of hard disk price. Secondly, TrainNet provides an alternative, economically viable, broadband solution to rural regions that are reachable via a railway network. Therefore, using TrainNet, rural communities will be able to gain access to bandwidth intensive digital contents such as music, video, television programs, and movies cheaply.

A key problem in TrainNet is resource scheduling. This problem arises because stations compete for the fixed storage capacity on each train. To this
end, this thesis is the first to propose three max-min scheduling algorithms, namely LMMF, WGMMF and GMMF, for use in challenged networks. These algorithms arbitrate the hard disk space among competing stations using local traffic information at each station, or those from other stations. To study these algorithms, the Unified Modeling Language (UML) is first used to construct a model of TrainNet, before a simulator is constructed using the DESMO-J framework. The resulting TrainNet simulator is then used to investigate the behavior of said max-min algorithms in scenarios with realistic traffic patterns. Results show that while LMMF is the fairest algorithm, it results in data loss and has the longest mean delay, the lowest average throughput, and the lowest hard disk utilization. Furthermore, Jain’s fairness index shows WGMMF to be the least fair algorithm. However, it avoids data loss as is the case with GMMF, and achieves the best performance in terms of mean delay, averaged throughput, and hard disk utilization.
Statement of Originality

This is to certify that the work described in this thesis is entirely my own, except where due reference is made in the text.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed

Mohammad Zarafshan Araki

..., 2009
Acknowledgments

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List of Abbreviations

AAA  Authentication, Authorization, and Accounting
ADSL Asymmetric Digital Subscriber Line
ARQ Automatic Repeat Request
AS Autonomous System
BGP Border Gateway Protocol
CATV Cable Television
DDoS Distributed Denial of Service
DRR Deficit Round Robin
DSL Digital Subscriber Line
DTN Delay Tolerant Networking
ECN Explicit Congestion Notification
EIGRP Enhanced Interior Gateway Routing Protocol
FCSF First Come First Served
GMMF Global Max-Min Fair
GPS Generalized Processor Sharing
GSM Global System for Mobile Communications
HFC Hybrid Fiber Co-axial
HIBC Hierarchical Identity-based Cryptography
HTTP Hypertext Transfer Protocol
I/O Input/Output
ICT Information and Communication Technology
IP Internet Protocol
IPN InterPlaNetary Internet
IS-IS Intermediate System to Intermediate System
ISP Internet Service Provider
<table>
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<tr>
<td>LAN</td>
<td>Local Area Network</td>
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<tr>
<td>LMMF</td>
<td>Local Max-Min Fair</td>
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<tr>
<td>MAP</td>
<td>Mobile Access Point</td>
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<td>MANET</td>
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<td>MBF</td>
<td>Mobile Bundle Forwarder</td>
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<td>MIM</td>
<td>Multipurpose Internet Mail Extensions</td>
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<tr>
<td>MPLS</td>
<td>Multiprotocol Label Switching</td>
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<tr>
<td>ONU</td>
<td>Optical Network Units</td>
</tr>
<tr>
<td>OSPF</td>
<td>Open Shortest Path First</td>
</tr>
<tr>
<td>PC</td>
<td>Personal Computer</td>
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<tr>
<td>PCMP</td>
<td>Persistent Connection Management Protocol</td>
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<td>PDA</td>
<td>Personal Digital Assistant</td>
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<td>PEP</td>
<td>Performance Enhancing Proxy</td>
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<tr>
<td>PKG</td>
<td>Private Key Generator</td>
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<tr>
<td>PKI</td>
<td>Public Key Infrastructure</td>
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<tr>
<td>POP</td>
<td>Point-of-Presence</td>
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<tr>
<td>QoS</td>
<td>Quality of Service</td>
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<tr>
<td>RAID</td>
<td>Redundant Array of Independent Disks</td>
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<tr>
<td>RMI</td>
<td>Remote Method Invocation</td>
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<tr>
<td>RPC</td>
<td>Remote Procedure Call</td>
</tr>
<tr>
<td>RTP</td>
<td>Real-time Transport Protocol</td>
</tr>
<tr>
<td>RTT</td>
<td>Round-Trip Time</td>
</tr>
<tr>
<td>SCTP</td>
<td>Stream Control Transmission Protocol</td>
</tr>
<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
</tr>
<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
</tr>
<tr>
<td>UML</td>
<td>Unified Modeling Language</td>
</tr>
<tr>
<td>UUCP</td>
<td>Unix-to-Unix Copy Program</td>
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<tr>
<td>VoD</td>
<td>Video on Demand</td>
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<td>Video Service Provider</td>
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<tr>
<td>WCATV</td>
<td>Wireless Cable Television</td>
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<tr>
<td>WFQ</td>
<td>Weighted Fair Queuing</td>
</tr>
<tr>
<td>WF²Q</td>
<td>Worst-case Fair Weighted Fair Queuing</td>
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List of Abbreviations

WGMMF  Weighted Global Max-Min Fair
WiFi    Wireless Fidelity