2306.
NETW 507

TBONES: a GMPLS Unified Control Plane for Multi-Area Networks

Dimitri Papadimitriou[1], Alcatel Bell (Antwerpen, Belgium)
Bela Berde, Alcatel CIT (Marcoussis, France)
Remi Theillaud, ATOS Origin (Paris, France)
Koen Casier, University of Ghent - IMEC (Ghent, Belgium)

Abstract—**Generalized Multi-Protocol Label Switching (GMPLS) has become the protocol suite of choice for unified control plane implementation. However, its adoption is facing major challenges in terms of control plane feasibility, performance, and gain when migrating from legacy packet over circuit multi-layer networks driven by overlaid control planes. The ITEA TBONES project aims at tackling both objectives through the development of a platform including network dimensioning and GMPLS control plane elements constituting such networks. This paper presents our methodological approach for the realization of this platform and the capabilities of the TBONES control plane emulator. Several experiments demonstrating its validity and capabilities including its applicability to multi-area networks will be exhibited during the Infocom 2005 demonstration session.**

I. INTRODUCTION

The benefits of a unified control plane (i.e. maintain a common control plane instance for a network hosting multiple switching layers) has become possible with the emergence of Generalized Multi-Protocol Label Switching (GMPLS) [1]. The objective of the TBONES control plane emulator is the validation of the control and the dynamic provisioning of multi-layer networks via a distributed and unified control plane based on the GMPLS protocol suite, as defined by the Internet Engineering Task Force (IETF). The TBONES project objectives also include the validation of the migration from an overlay (requiring a separate control plane instance per data plane switching layer) towards a unified control plane interconnection model where a single control plane instance drives a network hosting more than one data plane layer. Besides the verification of the proper operation of the GMPLS protocol suite in multi-area networks and Traffic Engineering (TE) algorithms, this project encompasses the quantification of the performance (in terms of resource and speed) of mechanisms such as constraint-based routing, and recovery (i.e. pre-planned and dynamic re-routing). Control plane interactions between the optical and the packet network (with a specific focus on IP/MPLS clients) are investigated. Finally, the TBONES emulator interfaces with the Dimensioning Tool (DT) external entity that calculates an adequate dimensioning for the topology according to an input traffic matrix.

This paper is organized as follows. In section II. we catalogue the TBONES control plane emulator components and describe their implementation. In section III., we detail the TBONES platform operations. Section IV integrates the experimentation aiming at validating the software development and the project technical objectives. Finally, we list in section V the main conclusions drawn from this work.

II. TBONES CONTROL PLANE EMULATOR

The TBONES Control Plane (CP) emulator is implemented as a set of processes running on Linux 2.6. It emulates the behavior of a set of nodes by instantiating for each node, a lower protocol stack and several control plane controllers. Each protocol stack implements the Open Shortest Path First - Traffic Engineering (OSPF-TE) [2] and the Resource Reservation Protocol - Traffic Engineering (RSVP-TE) [3] protocols, and runs in its own process. Each control plane controller set also runs in its own process, they communicate with each other through the protocol stacks. Each control plane controller consists of a set of modules: the Node Emulator (NE), Signaling Controller (SIGC), the TE Controller (TEC) and the Path Computation Controller (PCC).

The SIGC processes the trigger GMPLS RSVP(-TE) [4] signaling messages received from peering controllers. This controller is in charge of the Packet (PSC) and Lambda (LSC) Label Switched Paths (LSP) setup and release, and interacts for this purpose with the TEC. The following signaling procedures are supported: bi-directional LSPs, make-before-break, crankback, failure notification, dynamic and pre-planned re-routing, Soft-Permanent Connections (SPCs) and explicit label control. The SIGC relies on a Signaling Development Kit (SDK). The latter supports the communication with the lower protocol stack and its RSVP(-TE) component, and maintains a database of all LSPs known by this signaling controller.

The TEC processes signaling information such as explicit, record and exclude routes, or constraints (suggested label, label sets, etc.) to choose the component TE link for each LSP. The TEC relies on a generic TE Development Kit (TEDK) that supports the communication with the lower protocol stack and its OSPF(-TE) component, and maintains a database of all TE links (bundles and component links) advertised through OSPF(-TE). This database is the main input to the PCC, other inputs include crankback-related information [5] and signaled exclude route [6]. The OSPF(-TE) component maintains the routing adjacencies with peer nodes and the flooding of OSPF(-TE) Link State Advertisements (LSA) including global and per-interface mechanisms to limit the bandwidth consumed by such a flooding. The TEC updates information, e.g., per-priority Maximum LSP bandwidth advertised by GMPLS OSPF(-TE) [7], for the TE link(s) used by an LSP. It interacts with the NE for the reservation and allocation of local resources, and therefore for label allocation. The following TE procedures are supported:

[1] Corresponding Author: Alcatel Bell, Fr. Wellesplein, 1, B-2018, Antwerpen, Belgium - E-mail: dimitri.papadimitriou@alcatel.be

- *Multi-area Traffic Engineered (TE) LSP signaling* (using loose explicit routing)
- *PSC LSP over LSC Forwarding Adjacencies (FA) LSP*: the TEC can trigger the setup of additional LSC FA LSPs to fulfill new packet LSP requests; initial FA LSPs setup follow the topology computed by the DT from a given topology and traffic matrix, prior to the initialization of the simulation. The other LSC FA LSPs are dynamically triggered and setup on demand as needed.

III. TBONES Platform Operations

The different modules of the TBONES platform as well as the inputs/outputs and the information flows are depicted in Fig. 1. A network topology is used as input by the data and control plane modules. The traffic matrix is used by the DT that calculates an adequate routing and dimensioning for the network topology according to this matrix. The resulting output can be loaded by the control plane. The data plane gives to the control plane the scheduled LSC LSP requests, which are deduced from the traffic matrix. The TBONES emulator is implemented as a set of Linux processes that imitate a set of nodes by instantiating, for each node, a protocol stack and the set of GMPLS controllers. The former process provides a protocol stack that includes OSPF(-TE) and RSVP(-TE), and an IP stack to forward messages across the simulated IPv4 control channels. The protocol stacks exchange RSVP(-TE) and OSPF(-TE) packets through a process that emulates point-to-point sub-networks (software loopbacks). Moreover, each protocol stack may access to an Ethernet interface to communicate with the peering emulator(s). The protocol stack(s) attached to an Ethernet interface behaves as an IP router compared to the other protocol stacks. The second process, running on top of the protocol stack, implements the GMPLS controllers and a command engine agent that handles the communication with the emulator command engine.

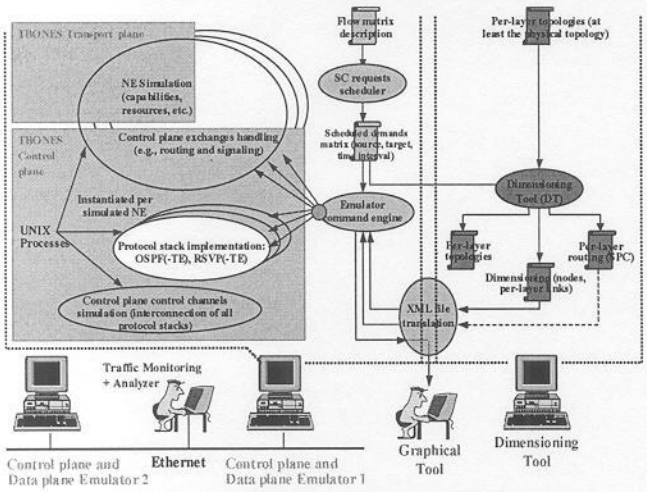


Figure 1. TBONES Information Flow and Processing

A protocol stack process never performs any blocking operation and is single-threaded. On the other hand, each control plane process is multi-threaded, one thread being used for each event: signaling messages, routing updates, and internal scheduler events (trigger of end-to-end LSP setup and teardown). Once a thread wakes up, it may run any of the controllers. The control plane emulator provides also a GUI command-engine, which allows its user to interactively query the different emulated nodes (dump of the signaling and traffic engineering databases; retrieval of statistics), and to generate data plane failures. The communication with the command-engine uses local sockets. Thus, there are three event sources: routing updates from the TEDK; signaling messages exchanged with peer signaling controller and received through the SDK, and commands from the emulator command engine.

IV. Testbed and Experiments

The TBONES control pane emulator provides some minimal data plane modeling as required for experimental support. The testbed includes, as depicted in Fig.1, two emulators hosted by two servers (running on Linux 2.6) that are interconnected by an Ethernet LAN segment. A special port is configured on the LAN switch to analyze the traffic flowing through this segment and graphically represent the OSPF routing adjacencies between nodes as well as the LSPs setup using GMPLS RSVP(-TE) signaling. A dedicated host system runs the DT and exchanges output results with the emulator using XML files. This system also provides graphical representation of the LSPs established in the network topology.

Several experiments aiming validation of the TBONES emulator implementation will be exhibited during the Infocom 2005 demo session. These experiments mainly include:

- The TBONES software validity including OSPF(-TE), RSVP(-TE) stacks and the different GMPLS controllers.
- The TBONES software supported load and performance (i.e. benchmarking) including OSPF(-TE), RSVP(-TE) stacks and the different GMPLS controllers. For instance, OSPF(-TE) implementation performance implies:
  (a) LSA/opaque TE LSA processing time: verify dependency on LS update packet size
  (b) LSA/opaque TE flooding (to neighbors) time: verify dependency on pacing (intervals)
  (c) SPF/CSPF computation time: verify dependency on the number of links and nodes
  (d) RIB/FIB update (CP level): verify de-correlation from number of link and nodes
  (e) Scalability enhancement delivered using link bundling on (a), (b) and (c)
  (f) Impact of multi-area exchanges on performance:
    - Type3_LSA: using an increasing number of inter-area prefixes until reaching saturation
    - Type4_LSA: using an increasing number of Autonomous System Boundary Routers (ASBR) with an increment of 1 until reaching saturation
    - Type5_LSA: from the previous increasing number of ASBRs, inject an increasing number of external prefixes per ASBR
- The capability to emulate multi-area TE environments as depicted in Fig. 2. The backbone Area 0, the Area 6, 66 and 77 belong to the same Autonomous System (AS), as depicted in Fig. 2. The backbone Area 0 is (among other) responsible for distributing routing information between non-backbone areas. Each Area Border Router (ABR) has complete topological information concerning the backbone,

AS-External prefixes, routes to ASBRs and summarized information from each area connected to the other ABRs. In their turn, the ABRs by flooding Link State Update packets populate their locally attached area Link State Databases (LSDB). Type10 LSA (Opaque Type 1) are exchanged within each area to describe the TE attributes of their internal links (in particular, the links interconnecting the Area 0 ABRs). The PCC uses this reachability information and the local area TE information, to compute loose routes from the ingress to the egress node (as determined by the request scheduler) associated to another area. Then, the SIGC initiates signaling of the multi-area LSPs.

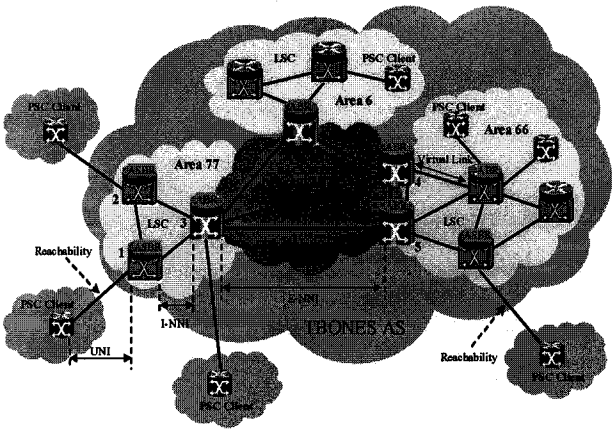


Figure 2. TBONES Multi-Area Routing Topology

- Pre-planned and dynamic end-to-end LSP re-routing. The former implies that the protecting LSP resources are allocated at the control plane level only and explicit action is required to activate (i.e. commit resource allocation at the data plane) during the recovery phase. Dynamic re-routing switches traffic to an alternate LSP that is fully established only after failure occurrence. The new alternate route is selected at the LSP head-end node, it may reuse resources of the failed LSP at intermediate nodes and may include additional intermediate nodes and/or links.
- The collaboration between the emulator and DT. This involves validation of the interface between the emulator and the DT and the capability to transparently exchange topological attributes through the dimensioning tool.
- The validation of the migration from an overlay towards a unified control plane interconnection model. For this purpose, the GMPLS-compliant User Network Interface (UNI) [8] for the overlay model is used for comparative purposes. In this model, no routing adjacencies are established between network edge and client nodes, but only between peering client nodes using the server layer LSP for the client routing adjacency establishment. Performance results are compared with those obtained with respect to the target models of the TBONES routing topology: 1) *Augmented model*: routing adjacencies between network edge and client nodes are used to exchange reachability information only. Depending on the addressing space two cases can be considered: separate control plane addressing space (between the client and the network): and common control plane addressing space: the control plane shares its address space with the network (at least its edges). 2) *Unified model*: routing adjacencies between network edge and client nodes are used to exchange reachability, topology and TE information.

It is also the objective of the TBONES project to assess the scalability (in terms of network size, traffic throughput and variations, as well as failures) of a distributed GMPLS control plane for PSC + LSC multi-layer networks. This experiment includes the evaluation of how multi-layer provisioning in a network undergoing traffic variations can reduce the LSP request blocking. For this purpose, a scheduled demand matrix is provided to the control plane, that triggers the setup and teardown of LSPs. Newly setup LSPs will accommodate increasing traffic demands, while LSP teardown happens for decreasing (or otherwise changing) traffic patterns to free capacity that can be used in other parts of the network. There exist multiple approaches to decide on the triggering of LSP establishment that translates a scheduled demand into a logical topology. The demand itself is presented as a collection of LSPs to be aggregated in this configurable logical topology.

V. CONCLUSION

The TBONES project aims at demonstrating the feasibility of a unified control plane using the innovative GMPLS protocol suite and mechanisms. Its complete validation (in terms of compliance and interoperability) and performance assessment experiments (benchmarking) are ongoing that will conclude a first development phase. This project also aims at demonstrating the relevance, the scalability and the gain obtained from the deployment of a unified control plane for multi-layer networks. Further experiments are currently conducted to validate different scenarios ranging from cost analysis of grooming strategies to the migration from overlay to unified control plane interconnection models.

REFERENCES

[1] E.Mannie (Editor) et al., "Generalized Multi-Protocol Label Switching (GMPLS) Architecture", RFC 3945, October 2004.

[2] J.Moy, "OSPF Version 2", RFC 2328, April 1998.
R.Coltun, "The OSPF Opaque LSA Option", RFC 2370, July 1998.
D.Katz et al., "Traffic Engineering (TE) Extensions to OSPF Version 2, RFC 3630, September 2003.

[3] R.Braden, et al., "Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification", RFC 2205, September 1997.
L.Berger, et al., "RSVP Refresh Overhead Reduction Extensions", RFC 2961, April 2001.
D.Awduche, et al., "RSVP-TE: Extensions to RSVP for LSP Tunnels", RFC 3209, December 2001.

[4] L.Berger (Editor), "Generalized Multi-Protocol Label Switching (GMPLS) Signaling Functional Description", RFC 3471, January 2003.
L.Berger (Editor), "Generalized Multi-Protocol Label Switching (GMPLS) Signaling - RSVP-TE Extensions", RFC 3473, January 2003.

[5] K.Kompella et al., "Routing Extensions in Support of Generalized Multi-Protocol Label Switching", draft-ietf-ccamp-gmpls-routing-09.txt (work in progress), October 2003.
K.Kompella et al., "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching", draft-ietf-ccamp-ospf-gmpls-extensions-12.txt (work in progress), October 2003.

[6] A.Farrel et al., "Crankback Signaling Extensions for MPLS Signaling", draft-ietf-ccamp-crankback-03.txt (work in progress),October 2004.

[7] C.Y. Lee et al., " Exclude Routes - Extension to RSVP-TE", draft-ietf-ccamp-rsvp-te-exclude-route-02.txt (work in progress), July 2004.

[8] G.Swallow et al., "GMPLS User-Network Interface (UNI): RSVP-TE Support for the Overlay Model," draft-ietf-ccamp-gmpls-overlay-05.txt (work in progress), October 2004.

IEEE Infocom 2005 Demonstration
ITEA TBONES Project

A GMPLS Unified Control Plane for Multi-Area Networks

D.Papadimitriou (Alcatel), B.Berde (Alcatel), K.Casier (IMEC), and R.Theillaud (Atos Origin)

TBONES

ITEA TBONES Project: Demo Infocom 2005

Hyatt Regency Hotel, Miami, FL, USA

ITEA

http://www.itea-office.org/index.php

ITEA TBONES Demo Session: March 16

iMinds

http://www.ibbt.be

Demo project partners:

Alcatel Bell (Belgium)

Alcatel B&I (France)

Atos Origin (France)

http://www.marben.com

University of Ghent – IMEC (Belgium)

ALCATEL

Atos Origin

ITEA TBONES Project: Objectives

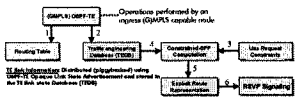
- ✓ Validation of dynamic Label Switched Path (LSP) provisioning in packet-optical multi-layer networks
- ✓ Traffic Engineering (TE) algorithms in single and multi-area networks
- ✓ Quantification of the performance (in terms of resource and speed) of constraint-based routing, pre-planned and dynamic re-routing
- ✓ Investigation of control plane interactions in packet-optical multi-layer networks (with specific focus on IP/MPLS)
- ✓ Interface with a Dimensioning Tool (DT) that calculates adequate dimensioning of the network topology according to a traffic matrix

ITEA TBONES Project: GMPLS Control Plane

Generalized Multi-Protocol Label Switching (GMPLS)

- ✓ Distributed IP-centric control plane
- ✓ Supports overlay and unified control plane interconnection model
- ✓ Control plane driven recovery (e.g. pre-planned and dynamic re-routing)
- ✓ Traffic Engineering (TE) for multi-area/multi-layer networks

Constraint-based Routing - Operations



TBONES Control Plane Emulator

Emulates the behavior of a set of nodes by instantiating for each node, a lower protocol stack and several control plane controllers.

Each protocol stack implements IETF GMPLS protocol suite:

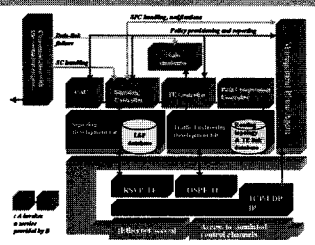
- ➢ Open Shortest Path First - Traffic Engineering (OSPF-TE)
- ➢ Resource reSerVation Protocol - Traffic Engineering (RSVP-TE)

Each control plane controller set runs in its own process, they communicate with each other through the protocol stacks

Each control plane controller consists of a set of modules:

- ➢ Node Emulator (NE)
- ➢ Signaling Controller (SIGC)
- ➢ TE Controller (TEC)
- ➢ Path Computation Controller (PCC)

TBONES Control Plane Software



Signaling Controller (SIGC)

Processes the trigger GMPLS RSVP(-TE) signaling messages received from peering controllers

Responsible for the Packet (PSC-) and Lambda (LSC-) LSP setup and release, and interacts for this purpose with the TEC

The following signaling procedures are supported:

- ➢ Bi-directional LSPs
- ➢ Crankback
- ➢ Multi-area LSP provisioning: loose explicit routing + exclude route
- ➢ Failure notification
- ➢ Pre-planned LSP re-routing: secondary LSP activation
- ➢ Dynamic LSP re-routing: make-before-break
- ➢ LSP Hierarchy: Forwarding Adjacencies (FA-LSPs)
- ➢ Soft-Permanent Connections (SPCs): Explicit label control

The SIGC relies on a Signaling Development Kit that maintains a database of all LSPs

Traffic Engineering Controller (TEC)

Processes signaling information such as explicit, record and exclude routes, or constraints (suggested label, label sets, etc.) to choose on per hop basis, component TE link for each LSP

Relies on a generic TE Development Kit (TEDK) that supports the communication with the lower protocol stack and its OSPF(-TE) component

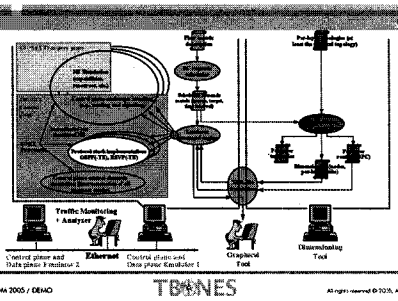
Maintains a TE database of all TE links (bundles and component links) advertised through OSPF(-TE)

- ➢ TE database is the main input to the PCC, other inputs include crankback-related information and signaled exclude route

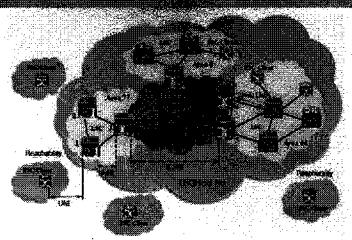
  Note: OSPF(-TE) component maintains the routing adjacencies with peer nodes and the flooding of OSPF(-TE) Link State Advertisements (LSA) including global and per-interface mechanisms to limit the bandwidth consumed by such a flooding

Updates TE link information, e.g., per-priority Unreserved and Maximum LSP bandwidth as advertised by OSPF(-TE), of each TE link used by an LSP

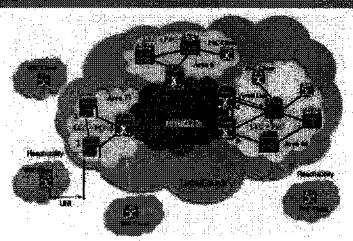
TBONES Test-bed



TBONES Multi-Layer Routing Topology



TBONES Multi-Layer Routing Topology



Some Experimentation Objectives

- ✓ Multi-area LSP provisioning: loose explicit routing
- ✓ Multi-layer LSP provisioning: nested PSC LSP provisioning into dynamically triggered/pre-provisioned nesting LSC FA-LSP
- ✓ Pre-planned and dynamic end-to-end LSP re-routing
- ✓ Collaboration between the control plane emulator and the Dimensioning Tool (DT)
- ✓ Validation of the migration from an overlay towards a unified control plane interconnection model

  Unified model: routing adjacencies between network edge and client nodes are used to exchange reachability, topology and TE information

Some Experiments

TBONES software validation including OSPF(-TE), RSVP(-TE) stacks and the different GMPLS controllers

TBONES software benchmarking (load and performance) including OSPF(-TE), RSVP(-TE) stacks and the different GMPLS controllers

Example: OSPF(-TE) implementation performance implies

a) LSA/opaque TE LSA processing time: verify dependency on LS update packet size

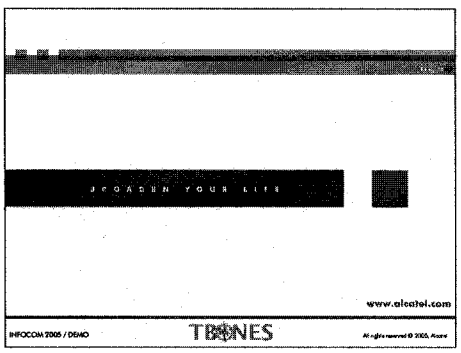
b) LSA/opaque TE flooding (to neighbors) time: verify dependency on pacing (intervals)

c) SPF/CSPF computation time: verify dependency on the number of links and nodes

d) RIB/FIB update (CP level): verify de-correlation from number of link and nodes

e) Scalability enhancement delivered using link bundling on a), b) and c)

f) Impact of multi-area routing exchanges on performance



IEEE INFOCOM 2005
Miami, Florida, USA
March 13 - 17, 2005

Poster/Demo Session Information

Poster/Demo Co-Chairs: Prof. Jennifer Hou, UIUC, Dr. Sai Shankar N., Philips and Prof. Krishna M. Sivalingam, UMBC

The slides/abstract PDF files are now available via this webpage and will be later directly available via INFOCOM webpage.

Instructions for Poster/Demo Session Presenters:

- **Registration:**
  - At least one poster/demo author should register for the conference by February 18, 2005.
  - One author's registration can count for up to two poster/demos.
  - If the poster/demo presenter plans to attend only for ONE day to present, he/she can register for ONE day registration.
  - Please visit INFOCOM 2005 website for registration information; Contact INFOCOM Registrar for registration related questions.
- **Hotel Reservations:** INFOCOM has extended the deadline for the Hyatt Hotel reservation where INFOCOM will be held. The new cutoff date for Hyatt Hotel is Feb 18th, 2005. Please make your reservation on or before Feb 18th in order to receive the conference hotel rate.
- For DEMO presentations: [Optional] An updated demo summary (PDF format) in IEEE two-column conference format that is up to 3 pages long may be submitted via your EDAS link by March 1, 2005. The abstract will be made available via INFOCOM webpage after March 1, 2005.

  Shipping address/information for sending demo components is available in Word Format.

  The demo teams are responsible for bringing any needed equipment to the conference.
- For POSTER presentations: Final copy of the POSTER slides, as a PDF file with 1 slide per page is due by March 1, 2005.

  [Optional] An updated poster summary (PDF format) in IEEE two-column conference format that is up to 3 pages long may also be submitted.

  The slides/abstract will be made available online via INFOCOM webpage after March 1, 2005.

Please upload the final versions via your EDAS paper link. [If two PDF files are being submitted, please submit a single ZIP or Tar-gzipped file]

- The conference will provide the following:
  1. A 6 foot by 18 inch table, a chair, Poster Easel/Board (4 feet by 8 feet), 22 inch by 28 inch foam board on which the presentors can stand, and Wireless Network Connectivity.

     Authors can arrange posters as A4/letter size copies of PPT slides, two 2'x4' posters, etc.
  2. The hotel will provide 110V power outlets. Demo presenters are responsible for getting their needed voltage conversion adapters, network hubs, etc.

     Shipping address/information for sending demo components is available in Word Format.

     The demo teams are responsible for bringing any needed equipment to the conference.

Poster/Demo Session Schedule:

Note: All (but one) demos are scheduled for two sessions on Wednesday, March 16.

Tuesday, March 15, 2005, Poster Session 1: 10.30 AM - 1.00 PM

Topic 1: Protocol/Algorithm Design and Analysis

Title	Authors	Slides File	3-Page Abstract
On Optimal Admission Threshold for CDMA Systems Supporting Integrated Services	Dharma Agrawal, Wei Li(University of Cincinnati, USA)	Slides	Abstract
Dependency-Aware Packetization Problem in Progressive Meshes	Yan Gu(National University of Singapore, Singapore)	Slides	Abstract
Positioning Relay Nodes in an ISP Network	Meeyoung Cha, Sue Moon, Chong-Dae Park (KAIST, Republic of Korea), Aman Shaikh (AT&T Labs - Research, USA)	Slides	Abstract
Self-Adapting Network Topologies in Congested Scenarios	Vicent Cholvi, Victor Laderas (Universidad Jaume I, Spain), Luis Lopez, Antonio Fernndez (Grupo de Sistemas y Comunicaciones, Universidad Rey Juan Carlos, Spain)	Slides	Abstract
The Impact of Probe Traffic Scale on The Stability of Multihop 802.11 Networks	Kitae Nahm, Ahmed Helmy, C.C. Jay Kuo (University of Southern California, USA)	Slides	Abstract
Unstructured Peer-to-Peer Networks - Next Generation of	William Acosta, Surendar Chandra (University of Notre Dame, USA)	Slides	Abstract

Performance and Reliability			
The Impact of Mobility on the Mobility-Assisted Information Diffusion Protocol	Fan Bai, Ahmed Helmy (University of Southern California, USA)	Slides	Abstract

Topic 2: Network Monitoring, Measurement and Analysis

Title	Authors	Slides File	3-Page Abstract
A Measurement-based Analysis of Residential Multihoming	Ahsan Habib, John Chuang (University of California at Berkeley, USA)	Slides	Abstract
InTraBase: Integrated Traffic Analysis Based on a Database Management System	Matti Siekkinen, Ernst Biersack, Guillaume Urvoy-Keller (Institut Eurecom, France), Vera Goebel, Thomas Plagemann (University of Oslo, Norway)	NO Slides	Abstract
On Loss Prediction for Real-time Packet Audio	Lopamudra Roychoudhuri, Ehab Al-Shaer (Depaul University, USA)	Slides	Abstract
Generic Network Traffic Capture Platform Building on Network Processor	Tao He, Jiang Liu, Shijin Kong, Xiaoxin Shao, Changqing An, Xing Li (Tsinghua University, P.R. China)	NO Slides	Abstract
HISTORY: High-Speed Network Monitoring and Analysis	Falko Dressler (University of Erlangen, Germany), Georg Carle (Universitaet Tuebingen, Germany)	Slides	Abstract

Topic 3: RFID Networks

Title	Authors	Slides File	3-Page Abstract
An Adaptive Memoryless Tag Anti-Collision Protocol for RFID Networks	Wonjun Lee, Jihoon Myung (Korea University, Republic of Korea)	Slides	Abstract
REALMS - RFID Enabled Animated Space	Niranjan Niranjan, Aura Ganz (University of Massachusetts at Amherst, USA)	NO Slides	Abstract

Tuesday, March 15, 2005, Poster Session 2: 1.30 PM - 4.00 PM

Topic 4: System Deployment and Experiment

Title	Authors	Slides File	3-Page Abstract
Leopard: A Locality-Aware Peer-To-Peer System With No Hot Spot	Sanghwan Lee, Zhi-Li Zhang (University of Minnesota, USA)	Slides	Abstract
Developing and Deploying Multihop Wireless Networks for Low-Income Communities	Joseph Camp, Edward W. Knightly (Rice University, USA), William Reed (Technology For All, USA)	NO Slides	Abstract
MapWeb: A Location-based Converged Communication Platform	Dawei Huang (Lucent Technologies, P.R. China), Christine Liu (Bell Labs, Lucent Technologies, P.R. China), Stone Shi (Bell Labs Research China, P.R. China), Gavin Yang (Bell Labs Research China, P.R. China), Ludi Zheng (Bell Labs, Lucent Technologies, P.R. China), Zhiyu Zhou (Lucent Technologies, P.R. China)	Slides	Abstract
Mobile Hotspots	Daniel Ho, Shahrokh Valaee (University of Toronto, Canada)	NO Slides	Abstract

Data Transport Challenges in Emerging High-Bandwidth Real-Time Collaborative Adaptive Sensing Systems	Tarun Banka (Colorado State University, USA), Brian Donovan (University of Massachusetts, Amherst, USA), Chandra V Chandrasekar (Colorado State University, USA), Anura Jayasumana (Colorado State University, USA), James F. Kurose (University of Massachusetts at Amherst, USA)	Slides	NO Abstract
A Secret-Sharing-Based Digital Watermarking Method for Streaming Media	Katsunori Yamaoka (Tokyo Institute of Technology, Japan), Tastuya Yoshinaga (Kyoto University, Japan), Takashi Satoh (The University of Kitakyushu, Japan), Tetsutaro Uehara (Kyoto University, Japan)	Slides	Abstract
Design of the Transit Access Point Hardware Platform	Patrick Murphy, Patrick Frantz, Edward W. Knightly, Behnaam Aazhang (Rice University, USA)	NO Slides	Abstract
Deployment Considerations of Layer 1 VPNs Using PCEMP	Dipnarayan Guha (Information and Communications University, Republic of Korea)	Slides	Abstract

Topic 5: Wireless Sensor Networks

Title	Authors	Slides File	3-Page Abstract
Neighbor Based TDMA Slot Assignment Algorithm for WSN	Ranjeet Patro (Senior Software Engineer, Honeywell, India)	Slides	Abstract
Optimal Routing for Maximizing Lifetime of Wireless Sensor Networks	Cunqing Hua, Tak-Shing Yum (The Chinese University of Hong Kong, Hong Kong)	Slides	Abstract
Location-Centric Storage for On-Demand Warning in Sensor Networks	Kai Xing, Xiuzhen Cheng (The George Washington University, USA)	Slides	NO Abstract
SMTP: A Hop-by-Hop Congestion Control Protocol for Wireless Sensor Networks	Chonggang Wang, Kazem Sohraby (University of Arkansas, USA), Bo Li (Hong Kong University of Science and Technology, P.R. China)	Slides	Abstract

Topic 6: Network Simulation and Emulation Tools

Title	Authors	Slides File	3-Page Abstract
Using the NCTUns 2.0 Network Simulator/Emulator to Facilitate Network Research	Shie-Yuan Wang (National Chiao Tung University, Taiwan)	Slides	Abstract
J-Sim: An Environment for Simulation and Emulation of Wireless Sensor Networks	Ahmed Sobeih (UIUC, USA), Wei-Peng Chen (Fujitsu Labs. of America, Inc., USA), Jennifer Hou (UIUC, USA), Luke Kung (UIUC, USA), Ning Li (UIUC, USA), Hyuk Lim (UIUC, USA)	Slides	NO Abstract

Wednesday, March 16, 2005, Poster/Demo Session 3: 10.30 AM - 1.00 PM

Topic 7: Network Management

Title	Authors	Slides File	3-Page Abstract
Experimental User-Oriented Architecture for Rapid	Carolina Pinart, Raul Munoz, Jordi Cebria (Centre Tecnologic de Telecomunicacions de	Slides+Abstract	Abstract+Slides

Provisioning in IP/WDM Networks	Catalunya, Spain), Gabriel Junyent (Universitat Politecnica de Catalunya, Spain)		
Towards Internet-Wide Network Management	Ashish Agarwal (Microsoft Research, USA), Simone Nucci, Supratik Bhattacharyya (Sprint ATL, USA)	NO Slides	Abstract
A Generic, Flexible and Efficient Approach for Assessing Future Radio Access Network Evolution Scenarios	Rene Schafczik (Lucent Technologies, Germany), Anja Wiedemann (University of Duisburg-Essen, Germany)	Slides	Abstract
Efficient Management of Distributed Filters in Large Heterogenous IP Networks	Birger Toedtmann (Universitat Duisburg-Essen, Germany), Joachim Charzinski (Siemens AG, Germany)	Slides	Abstract
On-Demand Bandwidth Trading Markets for Multi-Layer Traffic Engineering Networks	Richard Rabbat, Takeo Hamada, Ching-Fong Su (Fujitsu Laboratories of America, USA)	Slides	Abstract
Ontology based Directory-Enabled Network (DEN) Initiative for Integrated Network Management	Dipnarayan Guha (Information and Communications University, Republic of Korea)	Slides	Abstract

Demos: **Demos are scheduled for both morning and afternoon sessions on Wednesday**

Title	Authors	Slides File	3-Page Abstract
Intel Mote: Sensor Network Technology for Industrial Applications	Ralph Kling, Robert Adler, Jonathan Huang, Vincent Hummel, Lama Nachman (Intel Corp., USA)	NO Slides	Abstract
An Application Demonstration of the Reliable Server Pooling Framework	Thomas Dreibholz (University of Duisburg-Essen, Germany), Erwin Rathgeb (University of Essen, Institute for Experimental Mathematics, Germany)	NO Slides	Abstract
The Open Network Laboratory	John Dehart, Fred Kuhns, Jyoti Parwatikar, Jonathan Turner and Ken Wong (Washington University in St. Louis, USA)	NO Slides	Abstract
Anemone: Edge-Based Network Management	Richard Mortier, Rebecca Isaacs, Austin Donnelly, Paul Barham (Microsoft Research, Cambridge, United Kingdom)	Slides	Abstract
Improved Compression-Latency Trade-Off through Delayed-Dictionary Compression	Yossi Matias, Raanan Refua (Tel-Aviv University, Israel)	NO Slides	Abstract
DIMES: A Distributed Architecture for Internet Measurement and Monitoring	Yuval Shavitt, Eran Shir (Tel Aviv University, Israel)	Slides	Abstract
TBONES: a GMPLS Unified Control Plane for Multi-Area Networks	Dimitri Papadimitriou (Alcatel, Belgium),Bela Berde (Alcatel Research & Innovation, France), Remi Theillaud (Atos Origin, France),Koen Casier (University of Ghent, Belgium)	Slides	Abstract
Realistic Multimedia Evaluation	Yuan Sun, Ian Chakeres, Elizabeth Belding-Royer (University of California, Santa Barbara, USA)	NO Slides	Abstract
	Joe Touch, Yu-Shun Wang, Venkata Pingali, Runfang		

Global X-Bone for Network Experiments	Zhou, Greg Finn (USC Information Sciences Institute, USA), Lars Eggert (NEC Europe Ltd. Network Laboratories, Germany)	Slides	Abstract
ReWINS: A Distributed Multi-RF/Sensor Wireless Control System	Harish Ramamurthy, Dhananjay Lal, Shiv Prabhu, Rajit Gadh (University of California - Los Angeles, USA)	NO Slides	Abstract

Wednesday, March 16, 2005, Poster/Demo Session 4: 1.30 PM - 4.00 PM

Topic 8: Nano Communications

Title	Authors	Slides File	3-Page Abstract
Exploratory Research on Molecular Based Nano Scale Communication	Tatsuya Suda, Akihiro Enomoto, Ryota Egashira, Tadashi Nakano, Micheal Moore (UC Irvine), Satoshi Hiyama, Yuki Moritani (NTT DoCoMo Inc.)	Slides	Abstract
Molecular Communication between Nanomachines	Yuki Moritani, Satoshi Hiyama (NTT DoCoMo Inc.), Tatsuya Suda Ryota Egashira, Akihiro Enomoto, Michael Moore, and Tadashi Nakano (UC Irvine)	Slides	Abstract
Engineered Cell-Cell Communication for Programmed Pattern Formation	Subhayu Basu and Ron Weiss (Princeton University)	Slides	Abstract
Molecular-scale Communication Inspired by Protein Motor Function	Kazuhiro Oiwa and Ferdinand Peper (Kansai Advanced Research Center, National Institute of Information and Communications Technology, Japan)	Slides	NO Abstract

Demos: **Demos are scheduled for both morning and afternoon sessions on Wednesday**

Title	Authors	Slides File	3-Page Abstract
Intel Mote: Sensor Network Technology for Industrial Applications	Ralph Kling, Robert Adler, Jonathan Huang, Vincent Hummel, Lama Nachman (Intel Corp., USA)	Slides	Abstract
An Application Demonstration of the Reliable Server Pooling Framework	Thomas Dreibholz (University of Duisburg-Essen, Germany), Erwin Rathgeb (University of Essen, Institute for Experimental Mathematics, Germany)	Slides	Abstract
ReWINS: A Distributed Multi-RF/Sensor Wireless Control System	Harish Ramamurthy, Dhananjay Lal, Shiv Prabhu, Rajit Gadh (University of California - Los Angeles, USA)	Slides	Abstract
The Open Network Laboratory	Jonathan Turner (Washington University in St. Louis, USA)	Slides	Abstract
Anemone: Edge-Based Network Management	Richard Mortier, Rebecca Isaacs, Austin Donnelly, Paul Barham (Microsoft Research, Cambridge, United Kingdom)	Slides	Abstract
Improved Compression-Latency Trade-Off through Delayed-Dictionary Compression	Yossi Matias, Raanan Refua (Tel-Aviv University, Israel)	Slides	Abstract
DIMES: A Distributed Architecture for Internet Measurement and Monitoring	Yuval Shavitt, Eran Shir (Tel Aviv University, Israel)	Slides	Abstract

TBONES: a GMPLS Unified Control Plane for Multi-Area Networks	Dimitri Papadimitriou (Alcatel, Belgium),Bela Berde (Alcatel Research & Innovation, France), Remi Theillaud (Atos Origin, France),Koen Casier (University of Ghent, Belgium)	Slides	Abstract
Realistic Multimedia Evaluation	Yuan Sun, Ian Chakeres, Elizabeth Belding-Royer (University of California, Santa Barbara, USA)	Slides	Abstract
Global X-Bone for Network Experiments	Joe Touch, Yu-Shun Wang, Venkata Pingali, Runfang Zhou, Greg Finn (USC Information Sciences Institute, USA), Lars Eggert (NEC Europe Ltd. Network Laboratories, Germany)	Slides	Abstract

Thursday, March 17, 2005, Poster/Demo Session 5: 10.30 AM - 1.00 PM

Topic 9: New Network and Protocol Architecture

Title	Authors	Slides File	3-Page Abstract
The Hydra Switch Architecture: a Simple, High Performance Alternative to VOQ	Wladek Olesinski, Peter Rabinovitch (Alcatel Networks Corporation, Canada)	Slides	Abstract
SWIFT: A High Capacity Wavelength-Striped Optically Switched Network with Electronic Control	Michael Dales (University of Cambridge, United Kingdom), Madeleine Glick (Intel Research, United Kingdom)	Slides	NO Abstract
TrueWay: A Highly Scalable Multi-Plane Multi-Stage Buffered Packet Switch	H. Jonathan Chao (Polytechnic University Brooklyn, USA), Jinsoo Park (Coree Networks, USA), Guansong Zhang (Polytechnic University, USA), Sertac Artan (Polytechnic University, USA), Shi Jiang (Polytechnic University, USA)	Slides	Abstract
Packet Level Symbiosis	Istvan Matyasovszki (University of Limerick, Ireland)	Slides	Abstract

Topic 10: Characterization of Wireless Physical Layer

Title	Authors	Slides File	3-Page Abstract
Distributed Spectrum Measurements Poster	Theodoros Kamakaris (Stevens Institute of Technology, USA)	Slides	NO Abstract
A Graphical Exploration of Non-uniform Errors	Laura James (University of Cambridge, United Kingdom), Andrew Moore (University of Cambridge, United Kingdom), Madeleine Glick (Intel Research, United Kingdom), Adrian Wonfor (University of Cambridge, United Kingdom)	Slides	NO Abstract
Analysis of Enhanced Radio Link Control Protocol for W-CDMA Networks	Ali Begen (Georgia Institute of Technology, USA), Alkinoos Vayanos (Qualcomm Inc., USA)	Slides	Abstract

Topic 11: Multicast

Title	Authors	Slides File	3-Page Abstract
Heterogeneous QoS Multicast in	Sai Sudhir Anantha Padmanaban, Manimaran Govindarasu, Srikanta Tirthapura (Iowa State	Slides	Abstract

DiffServ-like Networks	University, USA), Prasant Mohapatra (University of California, Davis, USA)		
Implicit Multicast: A Plug-and-Play infrastructure for Multi-party Multimedia Conferencing over the Internet [DEMO]	Thiruvengadam Venketesan, Wu-Hon Leung, Hemant Deokar, Victor Broto (Illinois Institute of Technology, USA)	Slides	NO Abstract
Wireless Stealth Multicast: Bandwidth Conservation for Last-Mile Wireless Clients	David Salyers, Xiaolong Li, Aaron Striegel, Surendar Chandra (University of Notre Dame, USA)	Slides	Abstract
A Viable Solution for Large Scale Multicast Support	Jun-Hong Cui (University of Connecticut, USA)	Slides	Abstract
Need-Driven Multicast Group Membership and Tree Updates in IP-Based Mobile Networks	Umit Demir, Kia Makki, Niki Pissinou (Florida International University, USA)	NO Slides	Abstract

Topic 12: Security

Title	Authors	Slides File	3-Page Abstract
Hi-KD: Hash-based hierarchical Key Distribution for Group Communication	Hani Ragab Hassan (Compiegne University of Technology, France), Abdelmadjid Bouabdallah (Universite de Technologie de Compiegne (UTC), France), Hatem Bettahar (University of Technology of Compiegne, Heudiasyc lab., France), Yacine Challal (Compiegne University of Technology, Heudiasyc lab., France)	Slides	Abstract
Traceback Assisted Denial-of-Service Mitigation in Wireline-Wireless Networks	Muthuprasanna Muthusrinivasan, Manimaran Govindarasu (Iowa State University, USA)	Slides	Abstract
SWAT: Small World-Based Attacker Traceback in Ad-hoc Networks	Yongjin Kim, Ahmed Helmy (University of Southern California, USA)	Slides	Abstract

Topic 13: Intellectual Property Analysis

Title	Authors	Slides File	3-Page Abstract
Analysis Of Intellectual Property For Third Generation Cellular Technology	David Goodman (Polytechnic University, USA), Robert Myers (Fairfield Resources International, USA)	Slides	Abstract