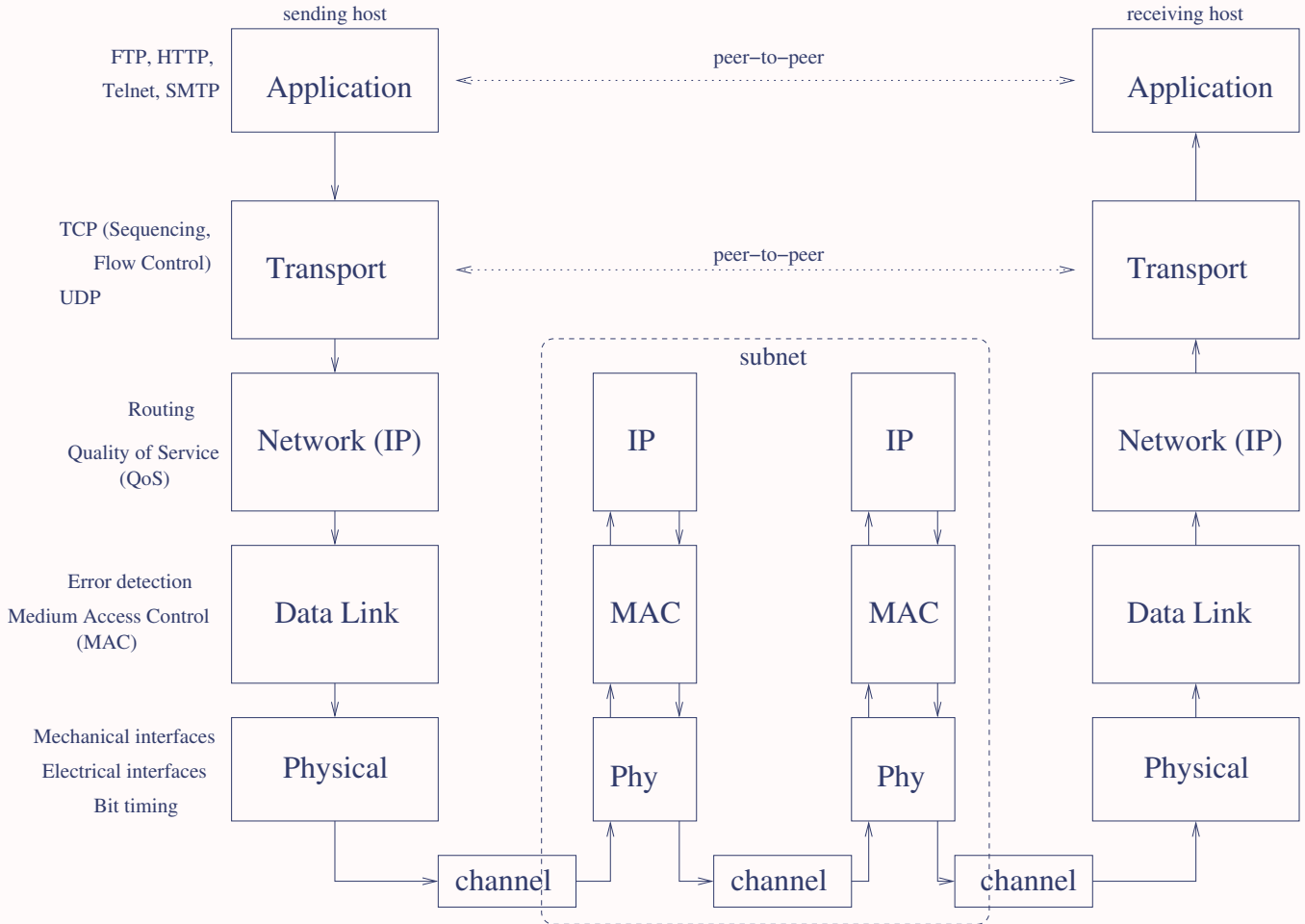


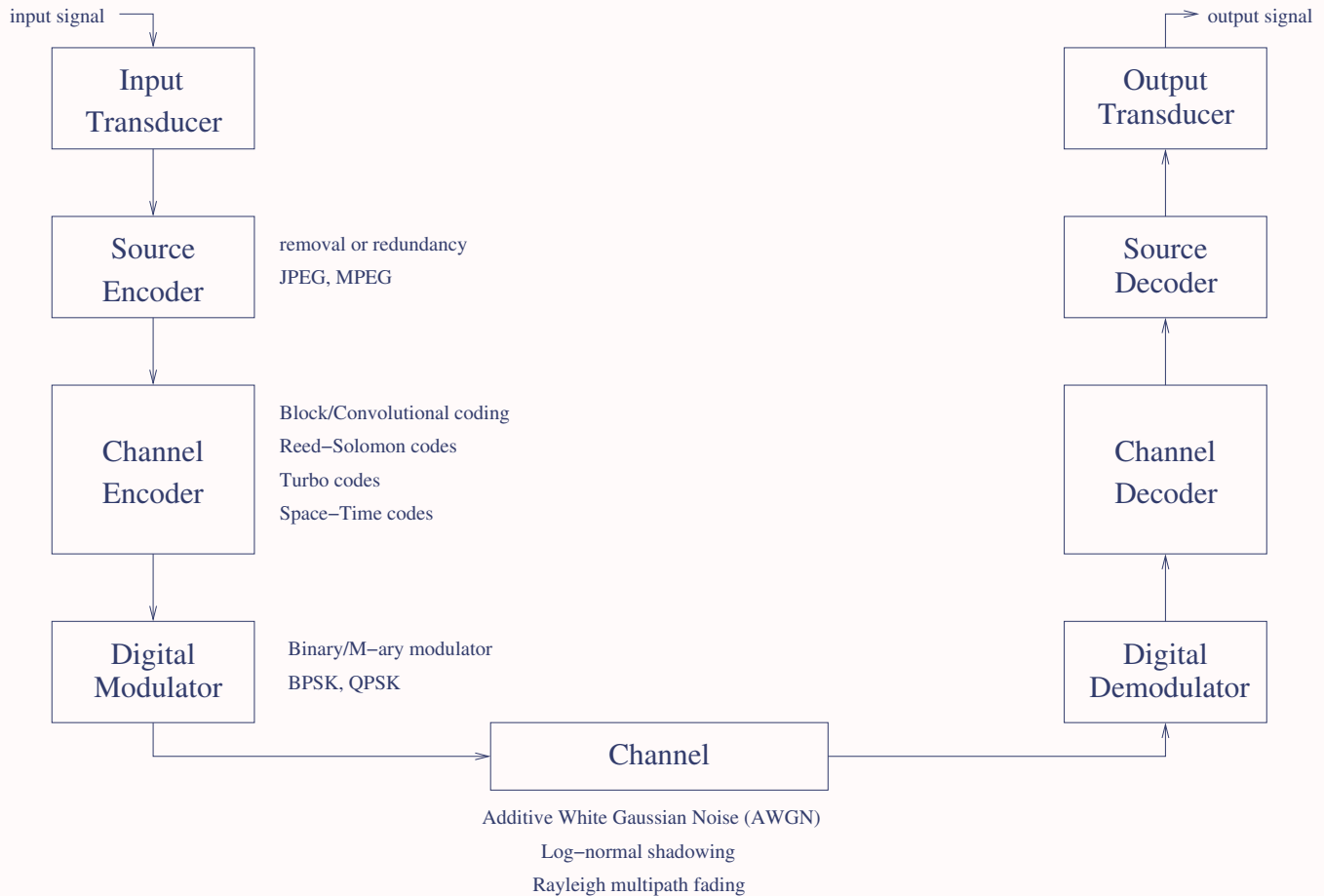
Information Networks Lab: Research Overview

Representative: Ashutosh Deepak Gore, Ph.D. student

OSI model of the Internet (software-centric)



Block diagram of a communication system



Faculty Members and their research interests

Prof. Abhay Karandikar

- CDMA wireless networks
- QoS guarantees in Communication Networks
 - Admission Control
 - Scheduling
 - Traffic regulation
- Mobile Ad-Hoc Networks
 - MAC layer
 - Routing
- Digital Communications
- Traffic Engineering (MPLS)
- Metro Ethernet

Prof. D. Manjunath

- Communication Networks
 - Protocols
 - Systems
 - Algorithms
- Performance Modeling and Evaluation
- Queueing Theory
- Simulation of Queueing Systems
- Stochastic Systems

Theory Group (AK)

1. Correlated Interarrival Time Poisson Process (CIPP) for Modeling Broadband Tele-traffic. (R. Manivasakan, Ph.D. 2000)
2. (a) Optimal Packet Length Scheduling for Regulated Media Streaming.
(b) Information Utility of a Token Bucket Regulator. (Premal Shah, DD 2003)
3. Rate Control and Synchronization Issues in Video Streaming over Packet-Switched Networks. (Neerav Mehta, B.Tech. 2003)
4. Optimal Scheduling for Power Efficient Transmission in Wireless Communication. (Mukul Agarwal)
5. Joint Admission Control and Scheduling Policies for Integrated Voice/Data CDMA Systems. (Shruti Mahajan, DD 2003)
6. Discrete-Rate Scheduling in wireless systems. (Siddharth Verma)
7. Power Control in CDMA Networks using Game-Theoretic Approach. (Kavitha Subramanian)
8. Routing in Time-Varying channels. (Nitin Salodkar)
9. Entropy-Optimal Generalized Token Bucket Regulator. (Ashutosh Deepak Gore)

Protocol Design and Evaluation Group (AK)

1. Adaptive Prediction based Approach for Congestion Estimation (APACE) in Active Queue Management. (Rahul Verma (DD 2002), Abhishek Jain (DD 2003), Shrinivas Kudekar (B.Tech. 2003))
2. A Grouping Framework for Reliable Multicast Congestion Control. (Harish Ramamurthy, DD 2003)
3. (a) Interference Based Multiple Access (IBMA) for CDMA-based Ad-hoc Networks.
(b) Resource Characterization and Achieving User Level Fairness in Multi-Class CDMA Ad-Hoc Networks.
(Manish Singh, Puneet Sahni, Jayesh Vyas (B.Tech., 2003), Prof. Krishna Paul)
4. B-Hive: A Cell Planning Tool for Urban Wireless Networks. (Harish Ramamurthy (DD 2003), Atit Jain, Hemant Kumar Rath)
5. TCP/IP Offload Engine for Storage Area Networks (Mandeep Singh Sidhu, B.Tech. 2003)
6. Implementation of Voice over IP over 802.11b Wireless LAN. (Siddharth Dachalwal)

Metro Ethernet and MPLS Group (AK)

1. Design of Layer-2 Virtual Private Network (L2VPN) and Customer's Edge device for Metro Ethernet services. (Hemant Kumar Rath)
2. Design of Provider's Edge Router for Ethernet Emulation over MPLS. (Siva Kumar D)
3. Design of a Policy Based Traffic Engineering Server for MPLS Network. (K Santhosh Kumar)
4. Voice over MPLS using Loop Emulation Service. (Medha Atre)
5. (a) A Linux based multi-threaded implementation of LDP signaling protocol.
(b) MPLS Forwarding Engine in Linux kernel.
(c) LiME: A Linux based MPLS Emulator.
(Abhijit Gadgil, Praveen Kumar and Ranoo Malhotra (all M.Tech., 2002))

Representative Research Papers (DM)

1. *Topological properties of wireless networks*
 - (a) A Distributed Control Law for Incremental Power Adaptation Based Topology Control of Ad Hoc Wireless Networks. (with Prof. Vivek S. Borkar)
 - (b) On the Connectivity in Finite Ad Hoc Networks. (with Prof. Madhav Desai)
2. *Internet Pricing and Queue Control*

DiffServ Node with Join Minimum Cost Queue Policy and Multiclass Traffic. (Rahul Tandra (B.Tech. 2003), Prof. N. Hemachandra)
3. *Optical Networks*

Multiperiod Virtual Topology Design in Wavelength Routed Optical Networks. (Pallavi Manohar (M.Tech. 2002), Ananth Padmanath, Sumit Singh (B.Tech. 2002))
4. *Packet Switch Architectures*

Input Queued Switches for Variable Length Packets: Analysis for Poisson and Self Similar Traffic. (Biplab Sikdar, M.Tech. IITK 1998)
5. *Internet Measurements and Tools*

Estimating Parameters of Segment QoS Measures on Network Paths. (Arati Tapase)
6. *Multimedia Transport*

Adaptive Streaming of Multimedia Over the Internet. (Nalin Agrawal)

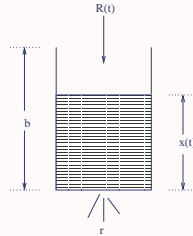
Information utility of a generalized token bucket regulator

Ashutosh Deepak Gore

Network Information Theory

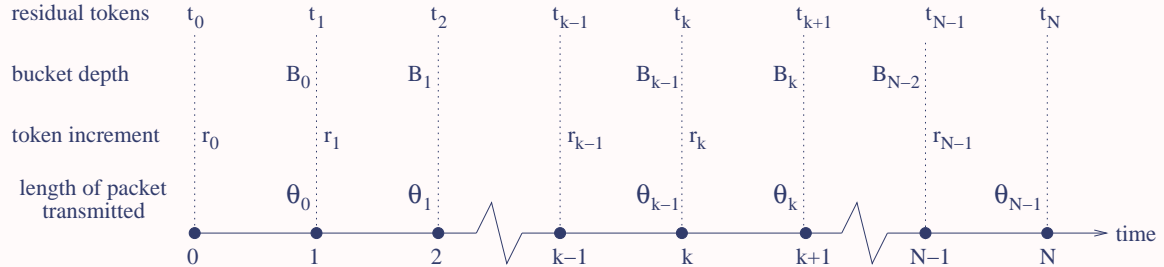
- Information theory [Shannon, 1948] is used:
 - to quantify meaningful measures (entropy) on sources and channels whose statistical properties are known.
 - to place an upper bound on the maximum amount of information (bits) that can be transmitted across a noisy channel within a certain error tolerance.
 - during the design stage of a communication system to accurately estimate its maximum data rate.
- Network Information Theory [Gallager, 1976] is used to:
 - derive a lower bound on the amount of protocol information that must be present in a data communication network.
 - characterize the burstiness (entropy) of traffic streams.
- In a data communication network, information can be conveyed by the contents, lengths and timings of packets only.

Token Bucket Regulator



- As a part of the Service Level Agreement (SLA) between an ISP and a subscriber, the ISP provides loss and delay guarantees to a subscriber provided the subscriber's traffic conforms to certain bounds.
- As a part of the SLA, a Token Bucket Regulator (TBR) is implemented at network ingress points to “envelope” the traffic of a subscriber.
- $R(t) - R(s) \leq r(t - s) + b \quad \forall t > s$
 - bursts of maximum size b are allowed
 - long-term average bit rate that enters the network is r
- TBR is useful for admission control.

System Model



- For a generalized token bucket regulator $\mathcal{R}(N, \mathbf{r}, \mathbf{B}, C_0)$, let
 - t_k = number of residual tokens in the bucket at time instant k ($t_0 = C_0$)
 - r_k = token increment at time instant k^+
 - B_k = bucket depth for the $(k + 1)^{th}$ slot, applicable at time instant $(k + 1)^-$
 - θ_k = length of packet transmitted at time instant $(k + 1)^-$
 - $p\theta_k$ = probability of transmitting a packet of length θ_k
 - $H_k(t_k)$ = entropy in the flow with t_k residual tokens
- Conforming packet lengths: $\theta_i \leq t_i + r_i$
- Token evolution equation: $t_{i+1} = \min(t_i + r_i - \theta_i, B_i)$

Computation of Flow Entropy

- After N transmissions, there is no more information left to transmit.

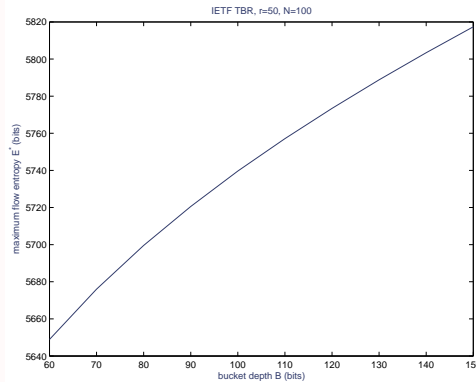
$$H_N(t_N) = 0$$

- Flow entropy can be computed backward-recursively.

$$H_k(t_k) = \sum_{\theta_k=0}^{t_k+r_k} p_{\theta_k}(t_k) [\theta_k - \log_2(p_{\theta_k}(t_k)) + H_{k+1}(\min(t_k + r_k - \theta_k, B_k))]$$

- Problem formulation:
 - Find the optimal probability distributions of packet lengths at every stage so as to maximize $H_0(C_0)$.
 - Information utility of the generalized token bucket regulator $\triangleq H_0^*(C_0)$
- Solvable by optimization techniques.
- Optimal flow entropy can be numerically computed.

Impact on Pricing



- A standard token bucket regulator is a GTBR for which the token increment rate and bucket depth do not vary from slot to slot, i.e., $r_i = r$ and $B_i = B$.
- From Matlab simulations, it has been found that information utility increases almost linearly with r and sub-linearly with B .
- A service provider can buy buffer space in bulk and sell it in chunks, thus making profit.

Generalized vs. Standard TBR

- “Can a generalized TBR can result in a higher information utility than a standard TBR?”
- For $\mathcal{R}(N, \mathbf{r}, \mathbf{B}, C_0)$ and $\mathcal{R}'(N', r', B', C_0')$ to be *comparable*, we require:
 - same interval of transmission ($N' = N$)
 - same initial token grant ($C_0' = C_0$)
 - same aggregate tokens over all slots ($r' = \frac{1}{N} \sum_{i=0}^{N-1} r_i$)
 - same aggregate burst size over all slots ($B' = \frac{1}{N-1} \sum_{i=0}^{N-2} B_i$)
- Simulations have shown that for a given standard TBR, there does exist a generalized TBR with higher information utility.

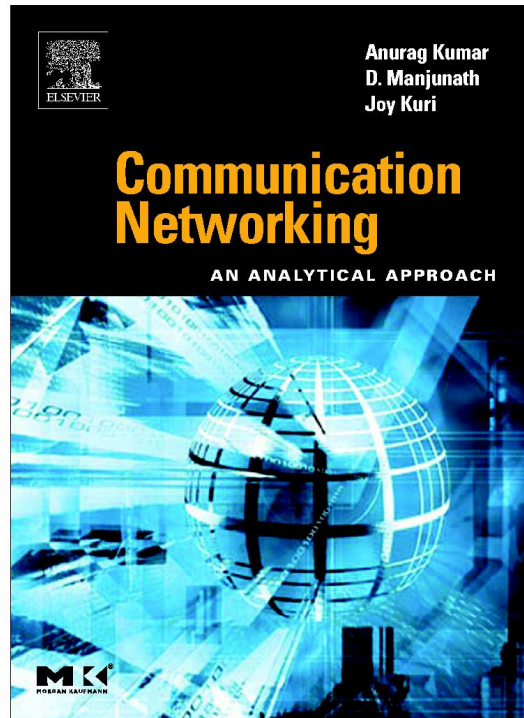
A practical perspective of the problem formulation

Given the total number of slots N , initial token grant C_0 , aggregate token increment M and aggregate bucket depth P , find the token increment vector $\mathbf{r} = (r_0, \dots, r_{N-1})$ and bucket depth vector $\mathbf{B} = (B_0, \dots, B_{N-2})$ so as to

$$\begin{aligned} &\text{maximize} && H_0^*(C_0) \\ &\text{subject to} && \sum_{i=0}^{N-1} r_i = M \\ & && \sum_{i=0}^{N-2} B_i = P \end{aligned}$$



Book by Prof.Manjunath



Company mentored by Prof. Karandikar

The goal of **Eisodus Networks** is to:

- Develop the technology of cost-effective broadband access.
- Leverage the potential of Ethernet for broadband access.
- Develop innovative architecture and algorithms for integrated voice, data and video with guaranteed QoS.

URLs

- Eisodus Networks
<http://www.eisodus-net.com>
- MPLS
<http://www.ee.iitb.ac.in/uma/~mpls/>
- B-Hive
<http://www.ee.iitb.ac.in/~bhive/>
- Wireless and Mobile Communications homepage
<http://sharada.ee.iitb.ac.in/~ee764/>

Thank you!

