IPTV Bandwidth Demands in Metropolitan Area Networks

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Introduction

- **Shift towards IPTV**
  - Converged voice, video, data networks
  - Unified management: OPEX savings
  - Emerging services: VoD (20% of users that have access to VoD use it daily), Gaming, Interactivity?
- **VoD is a bandwidth driver in MAN: Ability to generate multiple 100 Gb/s**
  - Amount of generated bandwidth depends on where VoD servers are located and caching of content
- **Large fraction of future traffic VoD: up to 90%**
  - Implications for network: QoS, unidirectional traffic patterns, large packets
- **This work:**
  - IPTV/VoD delivery in service provider network
    - Not Internet content delivery (YouTube, MovieLink, etc..)
    - Service provider determines caching locations
    - Centralized architecture (not peer-to-peer (P2P))
  - How much traffic on MAN network?
  - What is effect of caching content and delivering from an aggregation node?
  - What fraction of future traffic will be VoD?
Traffic Breakdown: Voice, Data, Video

- **Voice**
  - Traffic bandwidth usage predicted to remain nearly flat over the next 5 years:
    - \(~30 \text{ Gb/s} in 2005-2010\) for MAN with 1M households

- **Data (including P2P)**
  - Average sustained download rate of 41 kb/s (over 24 h per broadband user, 2005)
  - From peak-to-average bandwidth ratio of 1.44, obtain 60 kb/s per user in evening hours
  - Market study forecast of 55% growth/year → 340 Gb/s in 2010
    - Lower bound: 45% growth/year gives 160 Gb/s
    - Upper bound: 65% growth/year gives 620 Gb/s

- **Video**
  - Broadcast: 50 HD channels (8 Mb/s for HD) and 200 SD channels (2.3 Mb/s for SD) use only 0.9 Gb/s of BW in MAN
  - VoD: Potential for large amounts of bandwidth usage
VoD Network Architecture

- Based on service provider network architectures:
  - Layer of aggregation, optical MAN core w/ TDM and WDM
- VHO contain VoD servers that contain 100% of video content
- VSOs contain VoD servers with more popular content closer to users
- Unique HD stream sent to each user from VHO and VSO offices (assume HD, 8 Mb/s per stream)
Content Popularity

- 60,000 films - More than today’s VoD offerings, similar to Netflix
- Cache the more popular content at the VSO (closer to the end user)
- Zipf distribution: \( P = \frac{M}{k^a} \), \( k \) is popularity rank, \( a = 0.7 \) for VoD content
- Integrated Zipf distribution shows fraction of streams from VSO and VHO as function of \( R \)
Cost for Switching, Routing, and Transport

- **Routing & Switching**
  - Cost for the router cards with Ethernet interfaces and the number of routing hops traversed
  - Some streams served from VSO, some from VHO (cost never goes to zero)

- **TDM and WDM Transport & Switching**
  - Assume MAN core is TDM circuits connected with WDM transport system with optical bypass
  - Only the traffic served from VHO incurs TDM and WDM cost

- **VoD server cost**
  - Include film storage cost and cost per VoD stream
  - Film storage cost increases with more content cached at VSOs
Optimum Amount of Caching

- Optimum amount of caching \( (R_0) \) found at minimum total network cost
- \( R_0 \) becomes higher as the concurrency increases
  - At high VoD usage, more content should be delivered close to the end user
Optimum Caching Level

- At high VoD usage, more content should be delivered close to the end user
- When is all content delivered from VSO?
  - $25/film: R_0$ reaches 100% at low concurrency, 24%
  - $50/film: R_0$ reaches 100% at higher concurrency, 48%
  - $150/film$: some content always delivered from VHO
- Include OPEX overhead in cost
VoD Traffic in the MAN

- **Multiple 100 Gb/s generated in MAN**
  - MAN traffic peaks for low film caching cost as more content delivered from VSO
  - Argument for 100 GbE in the MAN network
- **VoD portion of MAN traffic can range up to 90% for no caching, and up to 40% for low storage cost**
  - VoD portion of MAN traffic given as fraction of total (voice + data + video)
  - Voice and data are projections for 2010 (30 Gb/s voice and 340 Gb/s data)
Conclusions

- VoD delivery has the capability to generate multiple 100 Gb/s of traffic in MAN
  - Driver for 100 GbE
- Large percentage of MAN traffic may be VoD traffic - up to 90%
- Local caching closer to the user reduces MAN traffic
  - For a large number of titles (e.g. 60,000) fraction of VoD traffic in the MAN can still reach 40% with low caching costs
- Implications for the network
  - Video sensitivity to loss
  - Low packet burstiness for smooth streams from server
  - Many large packets
  - Unidirectional
- Network can be optimized for VoD delivery
  - Asymmetric delivery with high bandwidth density
THANK YOU
MAN Voice Traffic

- Voice traffic bandwidth usage predicted to remain nearly flat over the next 5 years: 30 Gb/s in 2005, 31 Gb/s in 2010 for MAN with 1 M households
- Surveyed: Market studies forecasting subscription rate of mobile phones, fixed land lines, and VoIP lines
- Predict decline of PSTN lines but overall increase in phone connections due to growth in mobile and VoIP
- Growth in phone connections offset by decline in bandwidth per call due to PSTN replacement with more efficient VoIP and mobile lines
MAN Data Traffic

- From 2005 Japanese broadband access study, obtain average sustained download rate of 41 kb/s over 24 h per broadband user
- From peak-to-average bandwidth ratio of 1.44, obtain 60 kb/s per user in evening hours
- Market study forecast of 55% growth/year results in 540 kb/s in 2010
  - Lower bound: 45% growth/year gives 260 kb/s
  - Upper bound: 65% growth/year gives 980 kb/s
- Broadband penetration: 70%, Concurrency: 90%
- Ranges: 160 Gb/s → 340 Gb/s → 620 Gb/s in 2010
VoD Traffic, No Caching Limits

- Amount of traffic delivered from a single CO, VSO, and VHO assuming all content stored and streamed from that location (assume 8 Mb/s per stream)
  - CO traffic: below 10 Gb/s
  - VSO traffic: reaches 100 Gb/s
  - VHO traffic: multiple 100 Gb/s
- How does caching at the VSO reduce the VHO traffic?
Cost for Switching, Routing, and Transport

- **Routing and Switching:** \( C_{RS} = C_{EIF} \left( B_{VHO} \times H_{VHO} + B_{total} \times H_{total} \right) \)
  - \( C_{EIF} \): Cost for Ethernet interface, \( B_{VHO} \): BW delivered from VHO, \( H_{VHO} \): Number of routing hops this traffic undergoes

- **MAN core** consists of TDM switching nodes connected with WDM transport links with optical bypass for through traffic: \( C_{TDM+WDM} = B_{VHO} \left( C_{TDM} + C_{WDM} \right) \)
  - \( C_{TDM} \): Cost for TDM interface, \( C_{WDM} \): Cost for WDM interface

- **VoD server cost:** \( C_{Server} = C_{Storage} \left( R \times N_{VSO} + F \right) + C_{stream} \times N_{Sessions} \)
  - \( C_{Storage} \): cost/film for disk storage and management, \( N_{VSO} \): Number of VSO nodes, \( F \): total number of films offered, \( C_{stream} \): cost per VoD stream, \( N_{Sessions} \): number of simultaneous VoD sessions