



End-to-end Quality of Service

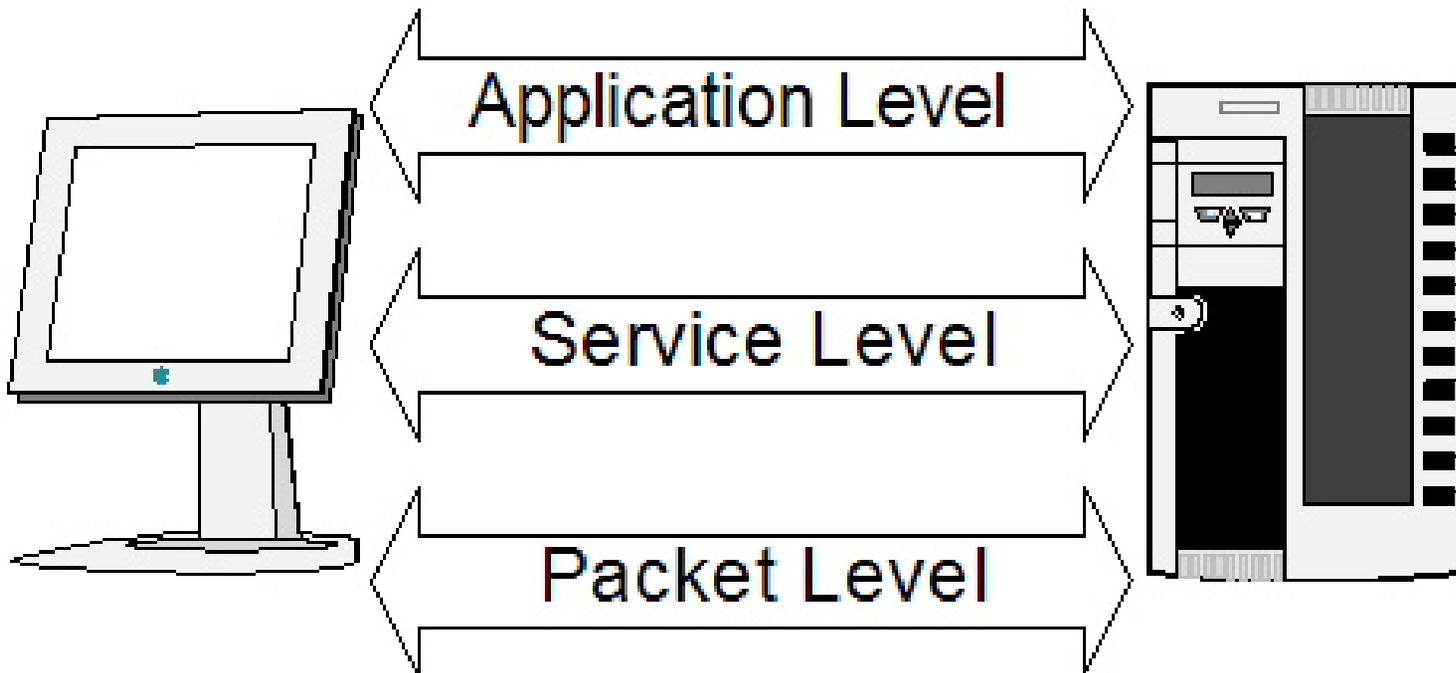
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[Conclusions]

- Major barrier to service-level interconnection is coordination
- Need a coordinator – an overlay
- Network Neutrality: justified
- Government could lead the way

Three Levels of Interconnection



[Structure of Talk]

- Narrowing the problem: video conferencing
- The stakes
- How stakeholders may solve the problem
- Government's role

High Quality Video Conferencing May Help Drive QoS

- Widespread VC foreseeable
- Needs considerable bandwidth
 - Could press existing network capacity
- HQVC has a money flow that helps answer “Who pays for the QoS”?
- QoS = Lack of jitter, lack of loss, low latency

Non-Internet Video Conferencing

- Multi-billion dollar industry
- Hard-wired conference rooms
- Private IP network or ISDN
- Dependable; good video quality
- Monthly costs are US\$ thousands
- *But can't conference with everyone you want*

Internet-Based Video Conferencing

- WebEx, Skype, NetMeeting
- Connect from anywhere
 - Another company, a laptop on the road
- Much cheaper
- But undependable

[Needed: Best of Both]

- Widely available
 - Over the Internet
- High-quality & dependable
 - Quality of HDTV

[Interconnection Is Lacking]

- There is no good QoS across ISP boundaries
- It is not a technical problem
- It is a problem of coordination of ISPs

Stakeholders' Interests

- Customer
 - Cannot sacrifice reliability, security
- Access ISP
 - Offering profitable HQVC-related services
 - Vertical integration
 - Offering HQVC to many points
- Backbone ISP
 - Profiting from carrying high-QoS traffic

[Stakeholders' Interests (2)]

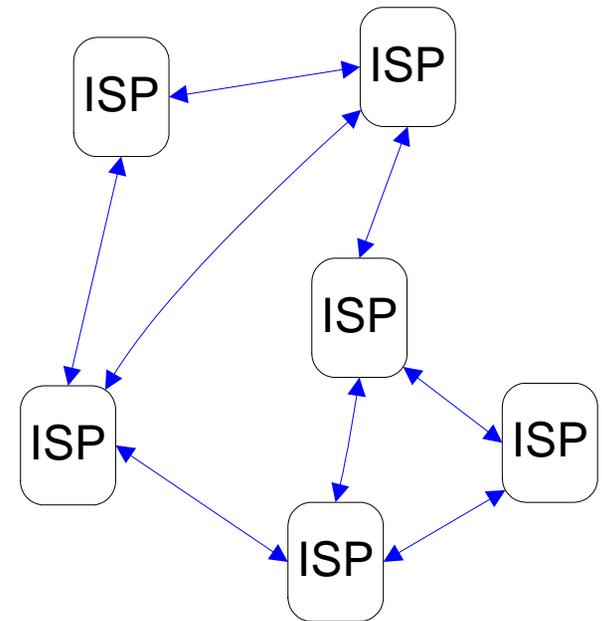
- Application Provider
 - Profit
 - Having QoS among many points
- Regulator
 - Avoiding inefficiencies we will discuss

[Possible Scenarios]

- ISPs *self-organize*
- App providers deal *individually* with ISPs
- Overlay *coordinates*

ISPs self-organize

- Currently unorganized
 - No industry-wide agreement on QoS
 - No standards / coordination initiatives
 - Money is left on table
- Need lots of arrangements
 - Each ISP negotiates with all/most of its neighbors



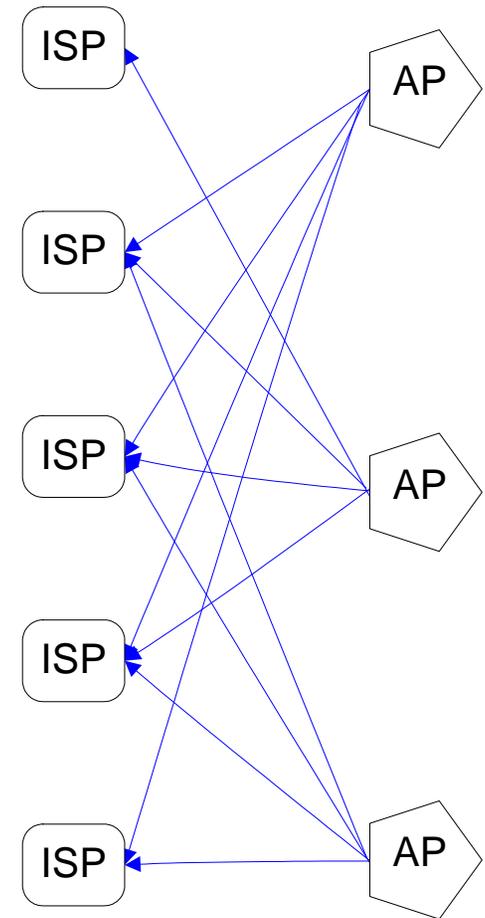
Business Arrangements

ISPs self-organize (cont'd)

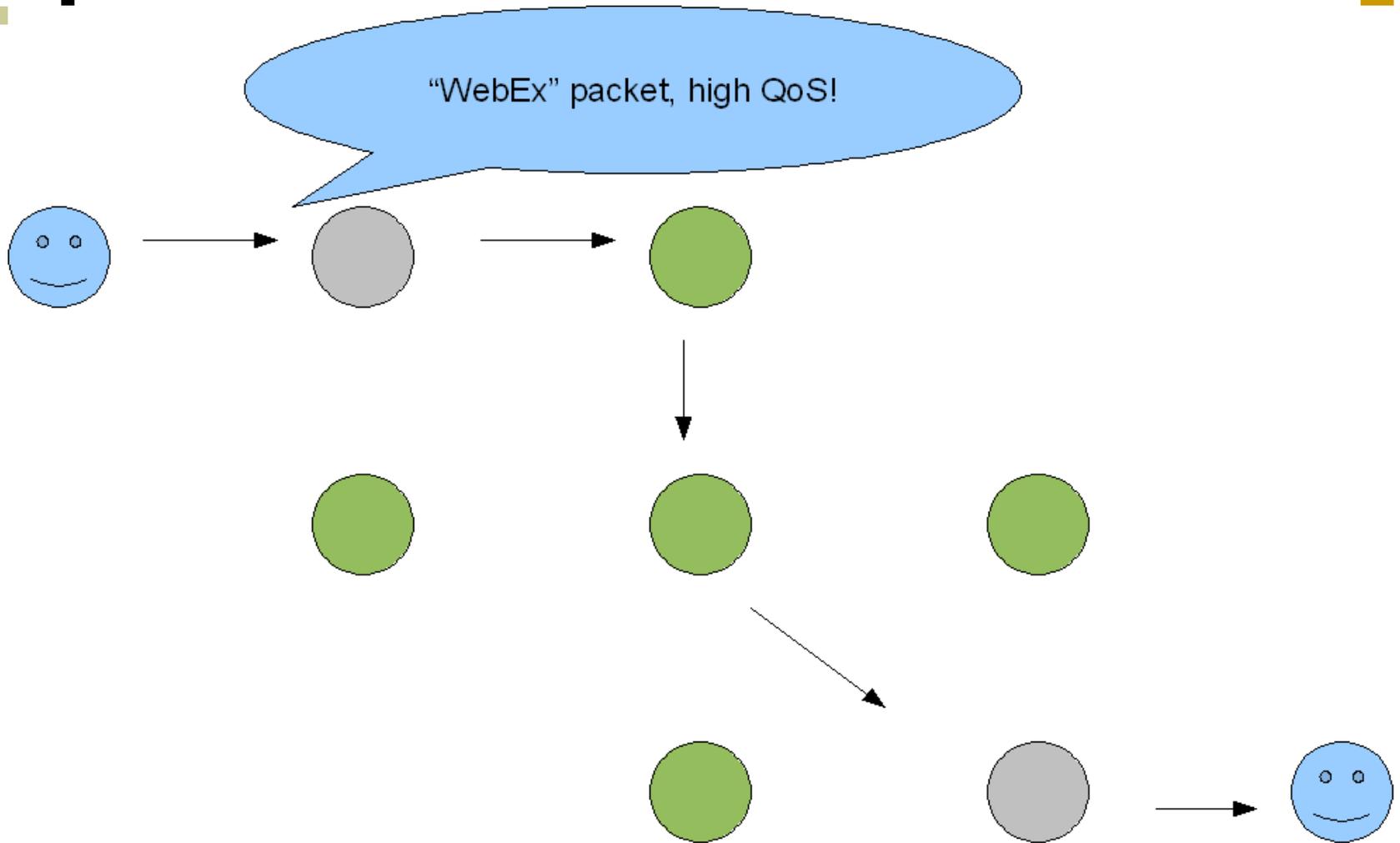
- Complex task to coordinate
 - Unclear compensation schemes
 - Pay by quantity? Pay by congestion?
 - Conflicting internal policies to optimize
- End-to-end QoS unlikely
 - More than agreeing to a standard – manage complex money flows
 - Possible fragmentation

[App Providers Deal with ISPs]

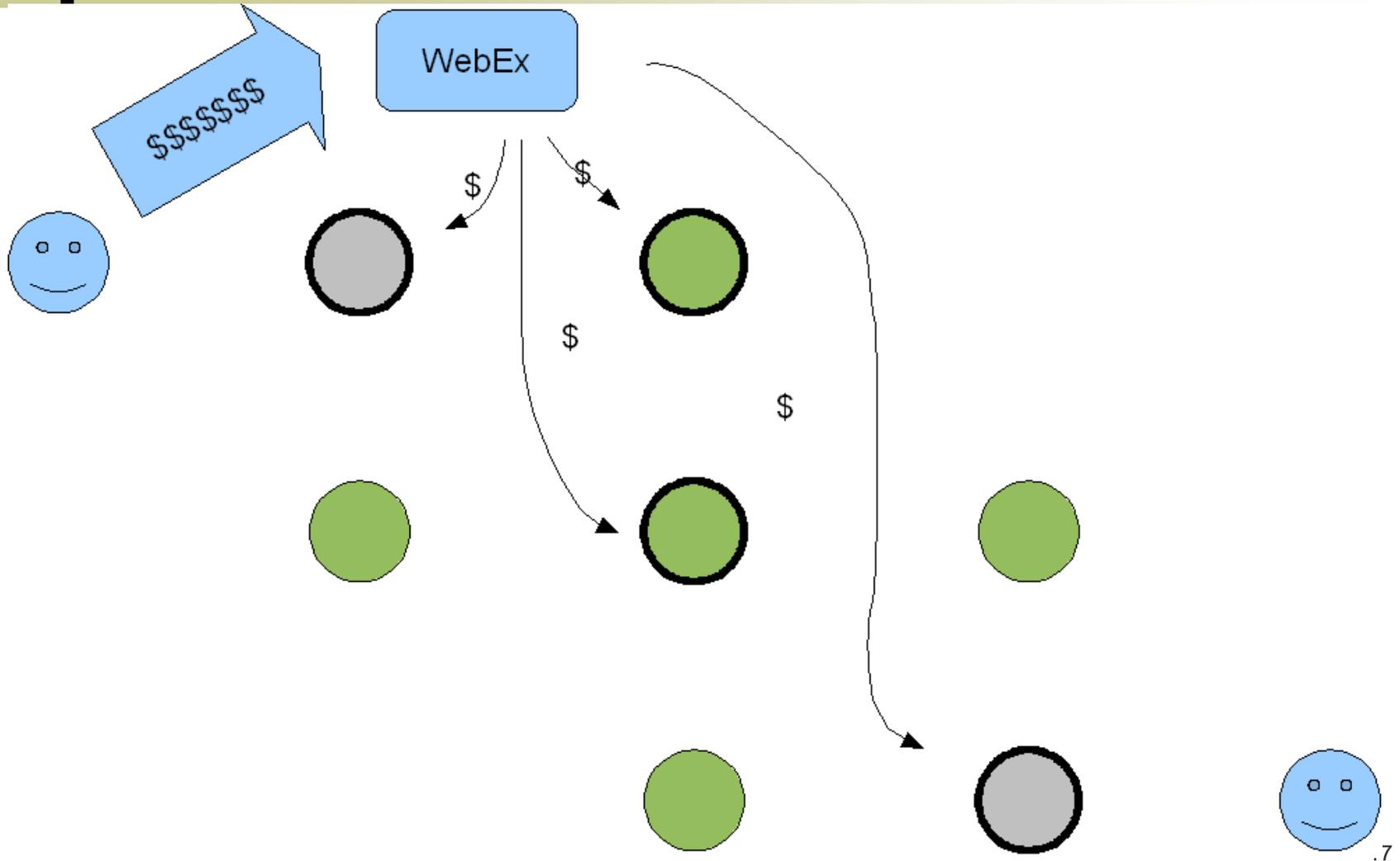
- High incentives
 - “Face” to the customers
 - Takes blame if low quality
 - No need to contact ISP for separate QoS
 - Possible strategic edge
 - Better service than competition
 - Co-market “bundles” with selected access ISPs



App Providers: Packet Flow



App Providers: Money Flow



[App Providers: Issues]



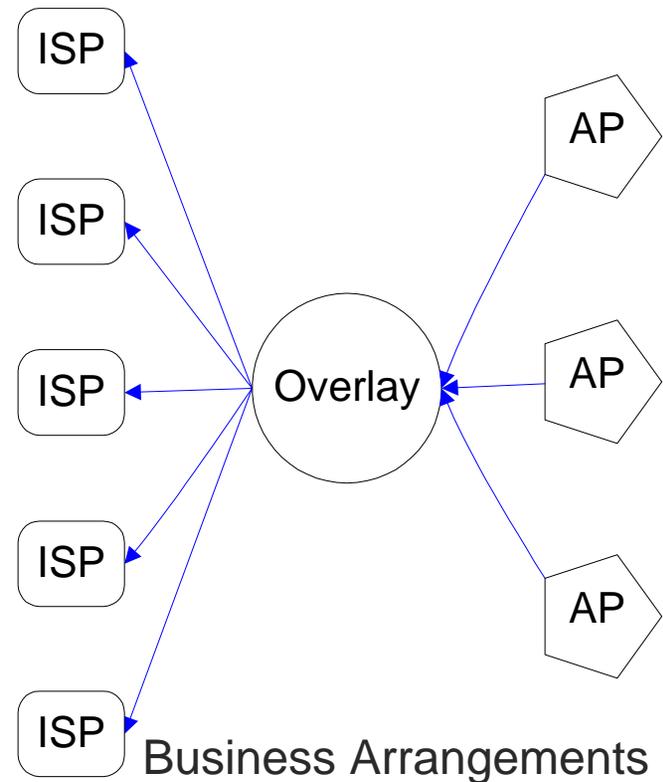
- Still very high costs to coordinate
 - Critical to partner with large ISPs
- App providers want exclusivity
 - Fragmentation possible
- Small app providers may be left out
 - High costs, no bulk discounts by ISPs
- Doubtful many app providers can coordinate a majority of ISPs

[Reality Check]

- Getting ISPs to self-organize is hard
- Getting App Providers to each organize with every ISP is hard
- Potential role for an overlay as a coordinator

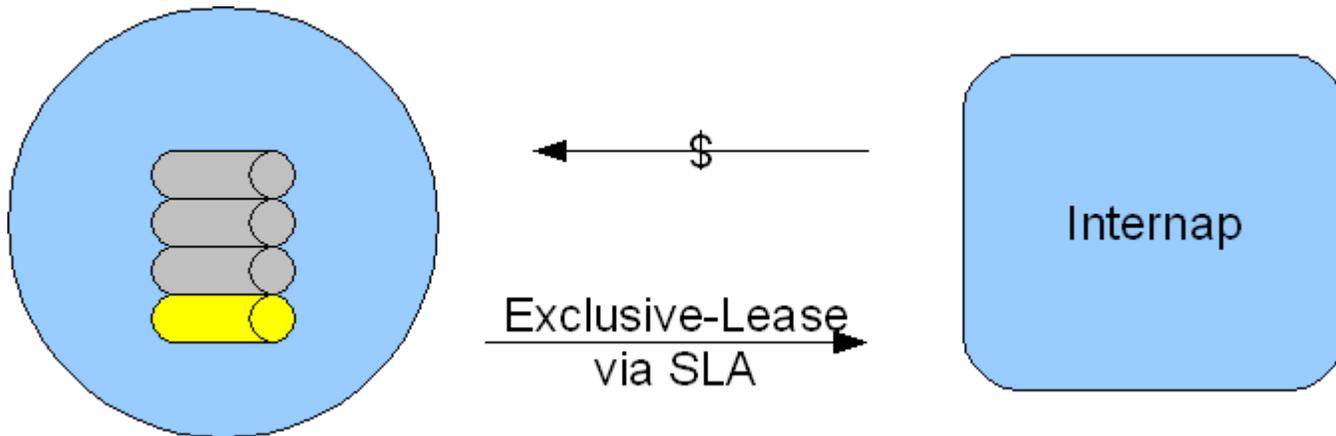
Overlay Drives Coordination

- Trusted 3rd party
- Overlay manages:
 - money flow
 - traffic through *preferred* ISPs
- Who pays whom:
 - Users pay APs
 - APs pay overlay
 - Overlay pays ISPs

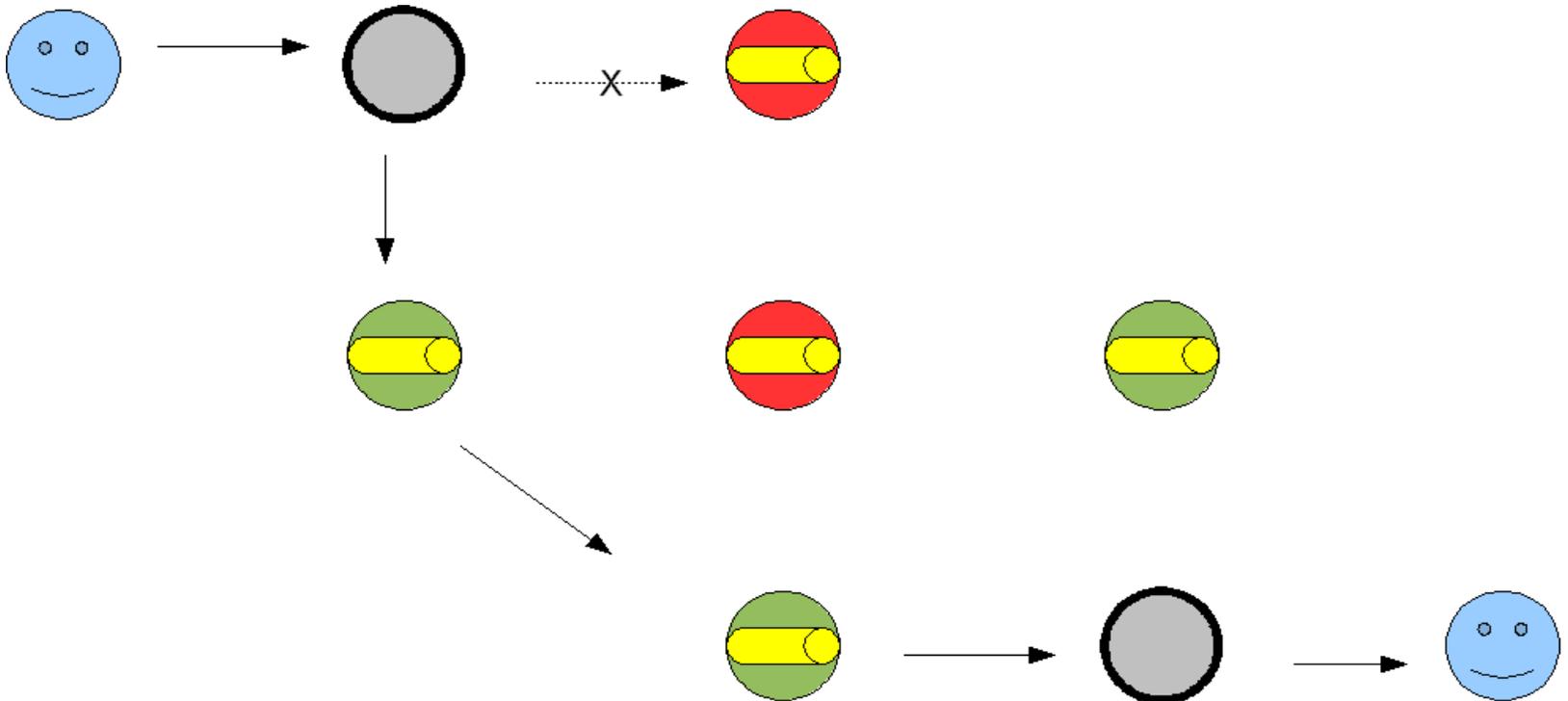


Case Study - Internap

- Lease bandwidth from backbone ISPs
- Provide very high dependability by avoiding ISPs with congestion



Internap Congestion Routing



But Internap doesn't offer last-mile QoS

[Overlay Benefits]



- For ISPs:
 - Can remain a “cloud” to other ISPs
 - Coordinate with one overlay
 - Lower cost than self-organizing
- For App Providers:
 - Large/small providers can get SLA
 - Deal only with overlay – no ISP
- For consumers:
 - Same way to sign up / get service
 - Extra fees, if any, paid only to app provider
 - Widely availability - can reach more users

Summary of Scenarios



	ISPs	App Providers	Overlay
# of Coordinations	# ISPs * # Neighbors	# ISPs * # Aps	# ISPs + # Aps
Fragmentation	Medium	High	Low
Trade Secret Sensitivity	High	Medium	Medium
Scalability for New Aps	High	Low	High

[Overlay: A Natural Monopoly?]

- High sunk cost: putting a system of coordination in place
- Low marginal cost: operating, adding new ISPs
- Network externalities; hard to start up
- But after it is done once, others may learn from example

[Network Neutrality]

- QoS is new revenue opportunity for ISPs
- If monopoly, overlay should be neutral for QoS traffic
 - More enforceable

[Network Neutrality (cont'd)]

- New problem: pro-QoS discrimination
 - ISPs degrade non-QoS traffic on purpose
 - Requires regulation?

[Government Initiates Overlay]

- Establish functional guidelines for overlay
- Oversee development of overlay
- Provide seed money

[Conclusions]

- Major barrier to service-level interconnection is coordination
- Need a coordinator – an overlay
- Network Neutrality: justified
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Overlay Definition (Clark et. al. 2005)



An Overlay is a set of servers deployed across the Internet that:

- a) provide some sort of infrastructure to one (or ideally several) applications,
- b) in some way take responsibility for the forwarding and handling of application data in ways that are different from or in competition with what is part of the basic Internet,
- c) are operated in an organized and coherent way by third parties (which may include collections of end-users) to provide a well-understood service that is infrastructure-like, but,
- d) are not thought of as part of the basic Internet.