EECS 122, Lecture 14

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Wide Area Multicast Delivery

- Simple approaches (flooding and ST modifications) don t scale so well
- Two Types of Distribution Techniques:
  - Source-Based Tree Approaches
    - build a distribution tree rooted at each sender
  - Shared Tree Approaches
    - one shared tree per group that hosts must attach to

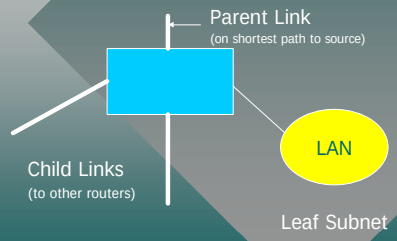
Source-Based ("shortest path ") Trees

- Build spanning trees rooted at each sender of each group
- Reverse Path Broadcasting (RPB)
- Truncated Reverse Path Broadcasting (TRPB)
- Reverse Path Multicasting (RPM)

Reverse Path Broadcasting

- Build a *simplex* spanning tree for each potential source [really source subnet]
- Given multiple senders per group, implies a different delivery tree for each source
- RPB Operation
  - for each each received packet, if it was received on the link on the shortest path back to the source, forward to all but the receiving link

Components



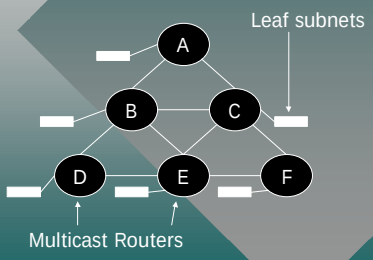
Reverse Path Forwarding

- Uses both source and destination addresses
- Algorithm:
  - look up source address in routing table
  - compare route entry with receiving interface
  - if wrong interface, drop
  - for each outgoing interface with group members downstream, forward packet

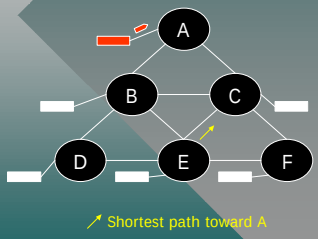
Implications of RPF Algorithm

- different tree for each source (source address identifies tree)
- tree is shortest path from source to destination (fastest delivery)
- packets spread over multiple links, leading to better network utilization

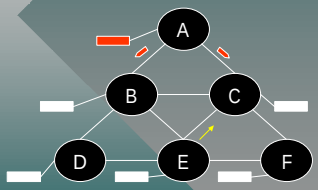
RPB Operation



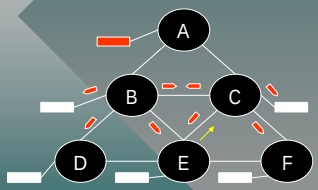
RPB Operation



RPB Operation



RPB Operation



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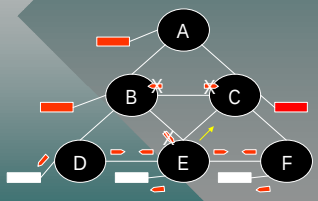
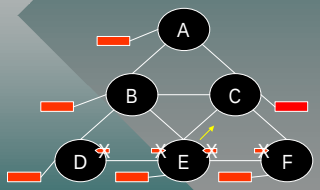
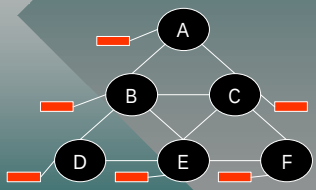


RPB Operation



RPB Operation



Observations

- Packet duplication due to flooding
- No use of global topology information or dynamic group membership
- Specialized forwarding algorithm:
  - RPF (reverse-path forwarding)

Extending RPB

- Improvement to RPB ("extended RPB"):
  - use routing protocol to detect which of neighbors links are parent links
  - can cut down some packet duplication
- Leaf subnets with no members still see traffic
- How to take advantage of group info?

Truncated RPB

- Use IGMP information to determine which leaf subnets contain members
- Routers don t deliver to subnets with no members
- Results:
  - saves some bandwidth on LANs, but does not address duplication across branches of distribution tree

Reverse Path Multicasting (RPM)

- Enhance RPB (TRPB) so that tree branches are activated only when necessary
- More precisely, tree branches only serve:
  - subnets with group members
  - routers and subnets along the shortest path to those subnets

Pruning the Distribution Tree

- RPM supports notion of "pruning" where routers can send messages indicating they should not receive traffic
- So, use TRPB algorithm for first packet to (source, group) pair
- Leaf routers with no group members send "prune" message on parent link ("broadcast and prune" approach)

Router Prune Processing

- (Upstream) routers receiving prune messages store them ("prune state")
- Routers with no local group members and that have received prunes on each child may, in turn, send prune on their parent links
- Cascade of prunes results in only "live" tree being used (to active receivers)

Reacting to Change

- Both topology and group members may change over time
- Thus, prune state contains a kill timer, and must be refreshed periodically (example of *soft state*)
- If kill timer expires but more traffic arrives, it is treated anew (using TRPB initially)

How Long to Age Prunes?

- Too long: join time unreasonable (prune state keeps data from flowing)
- Too short: back toward TRPB (extra traffic overhead)
- Solution, use longer values [default 2 hours] with prune cancellation messages (*grafts*)

Grafts

- Routers discovering new members for groups they have pruned may send graft messages to cancel existing prune state
- Grafts are reliably delivered
  - end nodes can t easily determined if a graft was lost or the sender stopped sending

Scaling Issues

- Multicast packets still periodically broadcast to all routers
- Each router must maintain (S,G) routing or prune state
- Biggest problem is when there is sparse membership across big internet (intermediate routers hold state)

Alternative Approaches

- approaches to handle multicast groups with "sparse" membership (widely distributed)
- keep state for receivers present rather than the reverse (assume non-membership rather than membership)
- do not keep state for each source

Shared Trees

- Idea is to construct a single tree (per group) that each source and receiver attaches to [spanning tree per group]
- Routers maintain only (*,G) state, not (S,G) state, leading to better scaling especially with many senders
- Do not require periodic flooding

Limitations

- Leads to traffic concentrations near core set of routers (routers on shared tree)
- May result in suboptimal routing to source

Perspective

- Dense Mode Protocols
  - bandwidth plentiful, receivers are densely distributed
  - assume membership, correct for mistakes
- Sparse Mode Protocols
  - bandwidth expensive, receivers are sparsely distributed
  - assume not members, require joins

Routing Protocols (briefly)

- Distance Vector
  - carries (cost, direction) information
  - each node has partial information
  - computation is distributed, relies on intermediates
- Link State
  - multicasts topology information to all routers
  - each router computes shortest paths

Dense Mode Protocols

- DVMRP (distance vector approach)
  - source-based trees using RPM
  - supports tunnels (IP/IP across unicast nets)
- PIM-DM (distance vector approach)
  - uses unicast routing tables
  - source-based trees using RPM
  - does not compute child interfaces

Dense Mode Protocols

- MOSPF (link-state approach)
  - no tunnels
  - SP trees built on-demand using entire topology database
  - no initial flooding, uses explicit join
  - not RPF based

Sparse Mode Protocols

- PIM-SM (PIM Sparse Mode)
  - uses unicast routing protocol information
  - routers must explicitly join shared tree
  - use rendezvous points (RP) for sources to meet receivers
  - routers must know RP set for region
  - joins are unicast toward RP
  - can switch dynamically to source-based tree

Sparse Mode Protocols

- CBT (Core Based Trees)
  - uses unicast routing protocol information
  - never switches to source based trees
  - tree branches are bi-directional, no special unicast encapsulation

Protocol Characteristics

- Use of unicast routing tables
  - PIM-SM and PIM-DM, CBT
- Link state or distance-vector
  - DV: DVMRP, LS: MOSPF
- Soft (DVMRP, PIM) or hard (CBT) state
- Sparse (PIM-SM, CBT), Dense (DVMRP)

Multicast Scope Control

- With multicasting, very easy to send traffic all over
- Would like to limit using scope control:
  - TTL scope: use TTL value in IP packets to limit number of hops traversed
  - Admin scope: allocate certain IP address ranges, and do not forward them

TTL Scope Control

- Assign TTL thresholds to each link:
  - if (packet TTL < threshold) drop packet
  - recall no ICMP time exceeded for multicast
- TTL Threshold Conventions:
  - 0: same host, 1: same subnet
  - 15: same site, 63: same region (west coast)
  - 127: worldwide, 191: worldwide, limited bw
  - 255: unlimited scope

Expanding Ring Search

- Can use TTL as a basis for searches
- Expanding ring search:
  - 1> start with TTL=1
  - 2> multicast query, await response
  - 3> if no response, increase TTL
  - 4> if TTL reaches max, failure
  - 5> go to step 2

Limitation of Expanding Ring Search

- TTL scoping requires "successive containment" property and will not work with overlapping regions
- In addition, routers which discard TTL-expired packets may not be capable of pruning sources, leading to excessive bandwidth consumption

Administrative Scoping

- Associate scope limitations with special address ranges (the 239/8 address block)
- Key properties [RFC 2365]:
  - packets addressed to admin scoped addresses do not cross admin boundaries
  - admin scoped multicast addresses are locally assigned; may be re-used in different administrative regions

Supporting Admin Scoping

- Routers support per-interface scoped IP multicast boundaries
- Does not forward packets in either direction across boundary
- Senders use admin scoped destination addresses, limiting overall distribution