CISCO IOS SOFTWARE RELEASE 12.2SXD ROUTING ENHANCEMENTS

INTERNET TECHNOLOGIES DIVISION

JULY 2004

Agenda

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- Introduction
- Border Gateway Protocol (BGP) Convergence Optimization
- BGP Dynamic Peer Groups
- Incremental Shortest Path First (iSPF)
- Intermediate System-to-Intermediate System (IS-IS) Exclude Connect IP Prefix From Label Switched Path (LSP)
- Open Shortest Path First (OSPF) Fast Hellos
- OSPF LSP Throttling
- Conclusion

Introduction

- Cisco IOS® Software Release 12.2(18)SXD consolidates recent routing enhancements previously available in Releases 12.0S and 12T
- Enhancements are mainly concerned with improving scalability and convergence time
- Permit a higher degrees of routing protocol customization, enabling customers to adjust those parameters applicable for their deployment

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BGP Convergence Optimization

- Refers to a series of BGP enhancements
- Cisco Routing Scalability Team analyzed the roadblocks in BGP convergence and addressed them individually
- Combination of code optimizations and deployment / configuration recommendations
- Results in this section are based on tests with 12.0S (where functionality was first released)

  12.2S benefits from this functionality; results should be comparable

BGP Initial Convergence

- **Involves advertising 120,000 routes to hundreds of peers**

  A vendor's implementation of BGP plays a major role in how fast a router can converge initially

- **Cisco IOS Software recently introduced a series of enhancements and fixes**

  NOTE: all graphs show the percentage improvement in the number of BGP peers which can be supported while still converging in less than 10 minutes

BGP Initial Convergence – TCP Interaction

- Conservative interaction between BGP and TCP resulted in slow UPDATE propagation
  - TCP frames were not being filled properly for maximum capacity
- Solution: alter BGP/TCP interaction to fill frames completely
- Simple solution provided a 133% increase in number of peers supported

BGP Initial Convergence – Peer Groups

- **Problem: advertise 120,000 routes to hundreds of peers. BGP will need to send a few hundred megs of data in order to converge all peers.**
- **Solution: use peer-groups**

  UPDATE generation is done once per peer-group

  The UPDATEs are then replicated for all peer-group member
- **Scalability and convergence is enhanced because more peers can be supported**

BGP Initial Convergence – Peer Groups

- **UPDATE generation without peer-groups**

  The BGP table is walked once, prefixes are filtered through outbound policies, UPDATEs are generated and sent…per peer!

- **UPDATE generation with peer-groups**

  A peer-group leader is elected for each peer-group. The BGP table is walked once (for the leader only), prefixes are filtered through outbound policies, UPDATEs are generated and sent to the peer-group leader and replicated for peer-group members that are synchronized with the leader

  Replicating an UPDATE is much easier/faster than formatting an UPDATE, which (unlike replication) requires a table walk and policy evaluation

BGP Initial Convergence – Peer Groups

Synchronization

- **A peer-group member is *synchronized* with the leader if all UPDATEs sent to the leader have also been sent to the peer-group member**
  - **The more peer-group members stay in sync the more UPDATEs BGP can replicate**
- **A peer-group member can fall out of sync for several reasons:**
  - **Slow TCP throughput**
  - **Rush of TCP Acks fill input queues resulting in drops**
  - **Peer is busy doing other tasks**
  - **Peer has a slower CPU than the peer-group leader**

BGP Initial Convergence – Peer Groups

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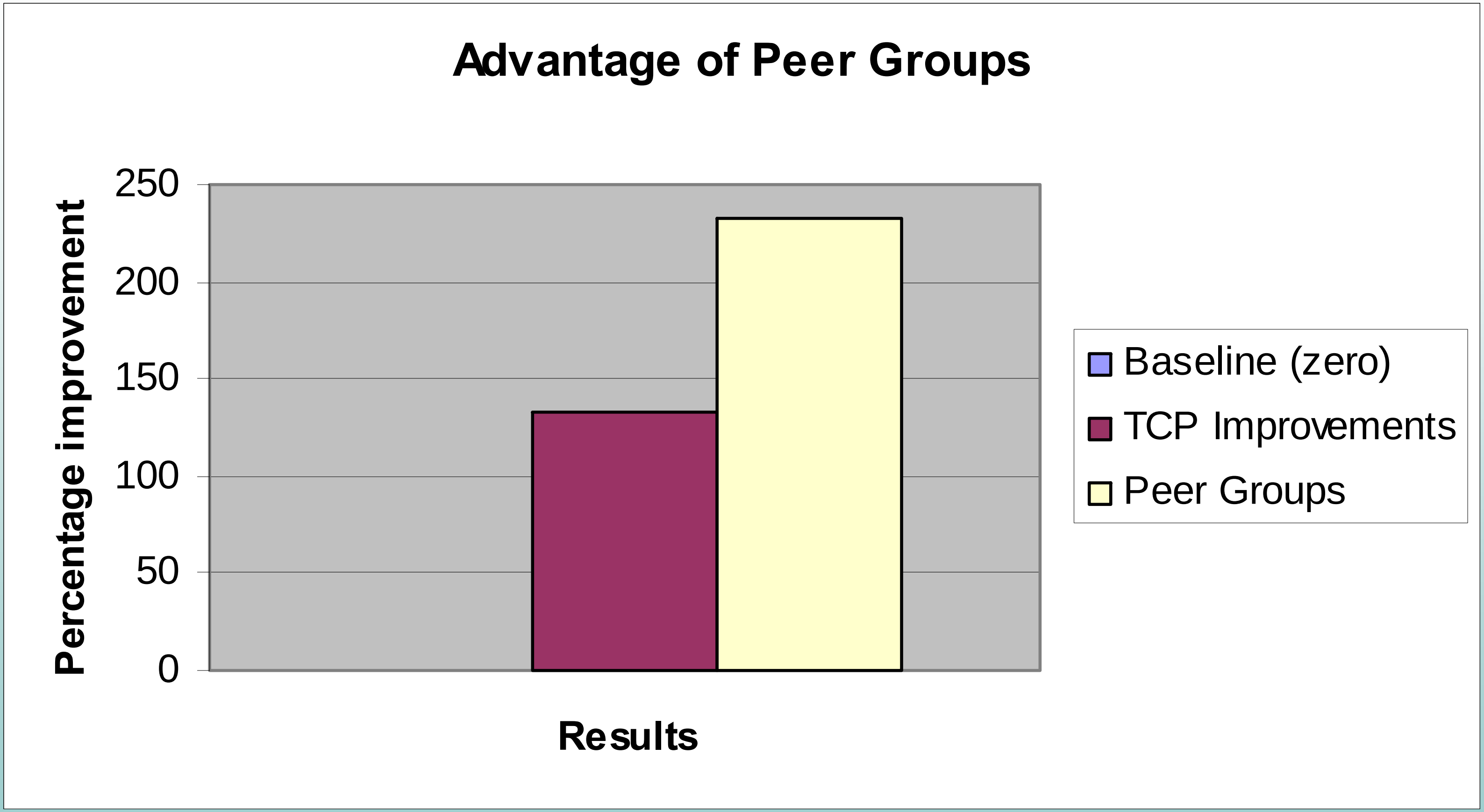
- **Peer-groups provide a significant increase in scalability**



BGP Initial Convergence – Input Queues

- If a BGP speaker is pushing a full Internet table to a large number of peers, convergence is degraded due to enormous numbers of dropped TCP Acks (100k+) on the interface input queue

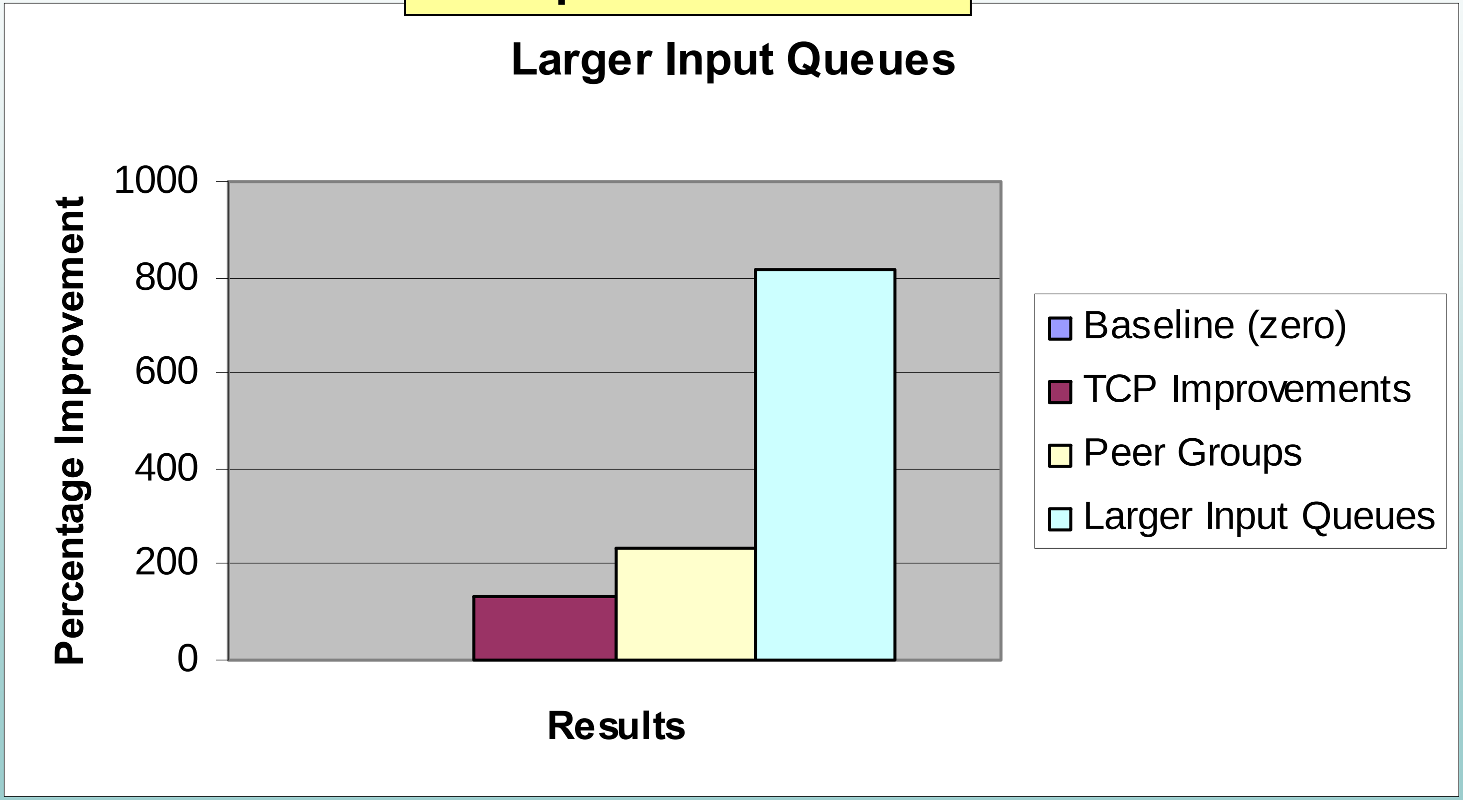
  Typical ISP gets ~½ million drops in fifteen minutes on an average route reflector

- Increasing the size of the input queue, thus reducing the number of dropped TCP Acks, improves BGP scalability, and reduces convergence

BGP Initial Convergence – Input Queues

- **Rush of TCP Acks from peers can quickly fill the seventy-five spots in process level input queues**
- **Increasing queue depths (4096) improves BGP scalability**

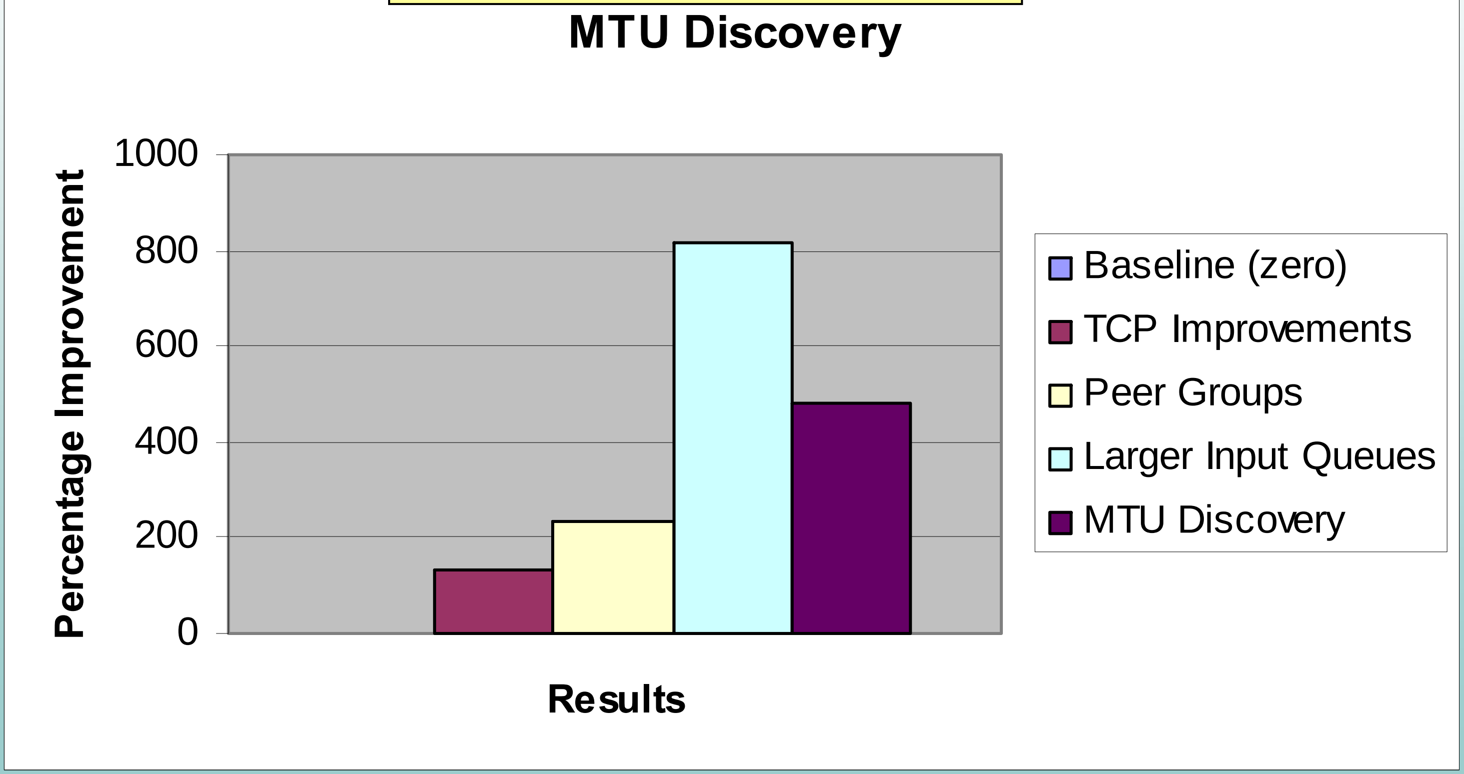
hold-queue <1-4096> in



BGP Initial Convergence – MTU Size

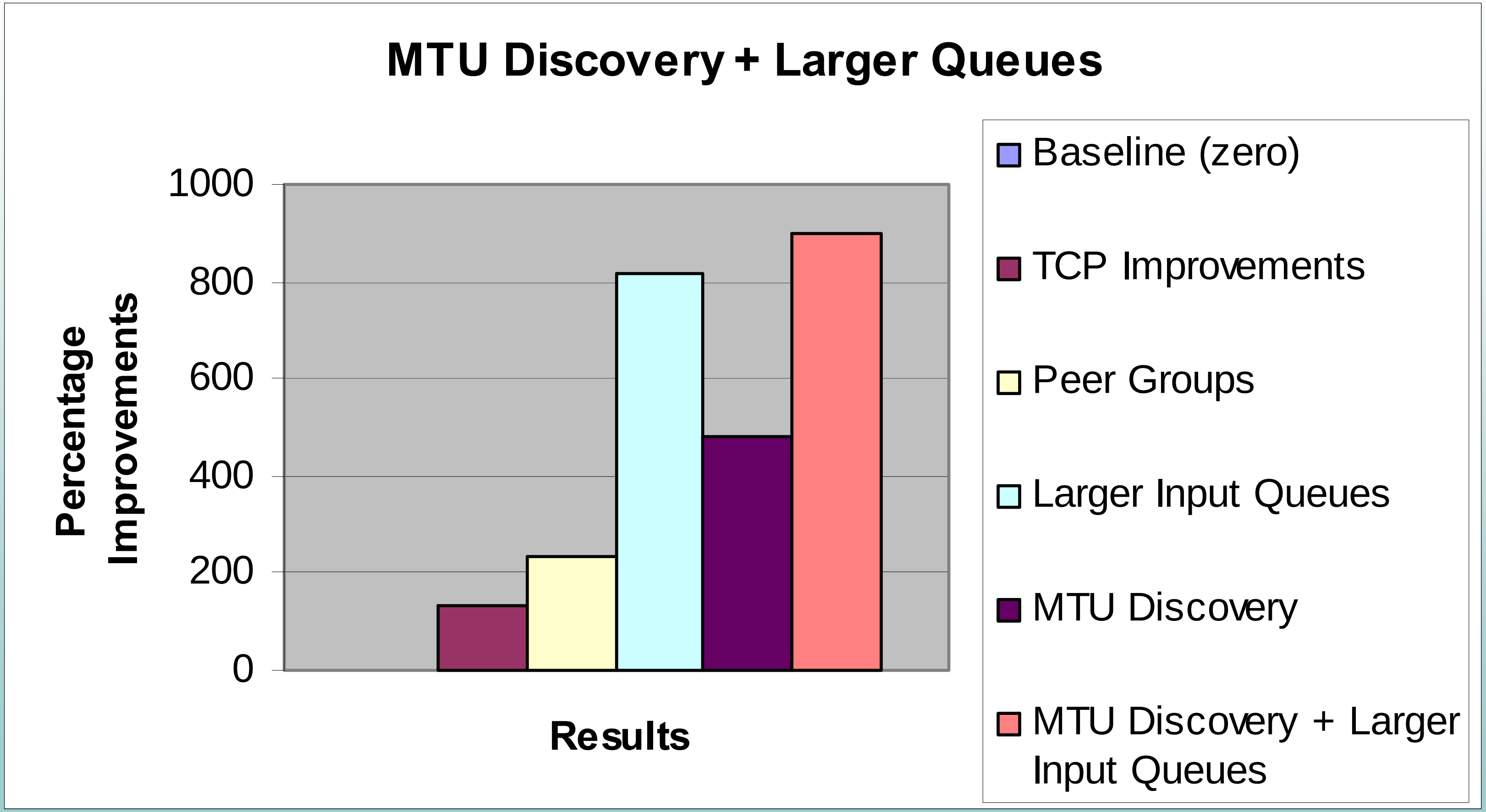
- Default MSS (Max Segment Size) is 536 bytes
- Inefficient for today's POS/Ethernet networks
- Using "ip tcp path-mtu-discovery" improves convergence

ip tcp path-mtu-discovery



BGP Initial Convergence – MTU Size

Simple config changes can give significant improvement



UPDATE Packing

- **A BGP UPDATE contains a group of attributes that characterize one (or more) prefixes**

  Ideally, all the prefixes that have the same attributes should be advertised in the same UPDATE message (use as few messages as possible)

  For example:

    BGP tables contain 100,000 routes and 15,000 attribute combinations: user can advertise all routes with 15,000 updates if prefixes can be packed 100%

    100,000 updates indicate that the user achieves 0% update packing

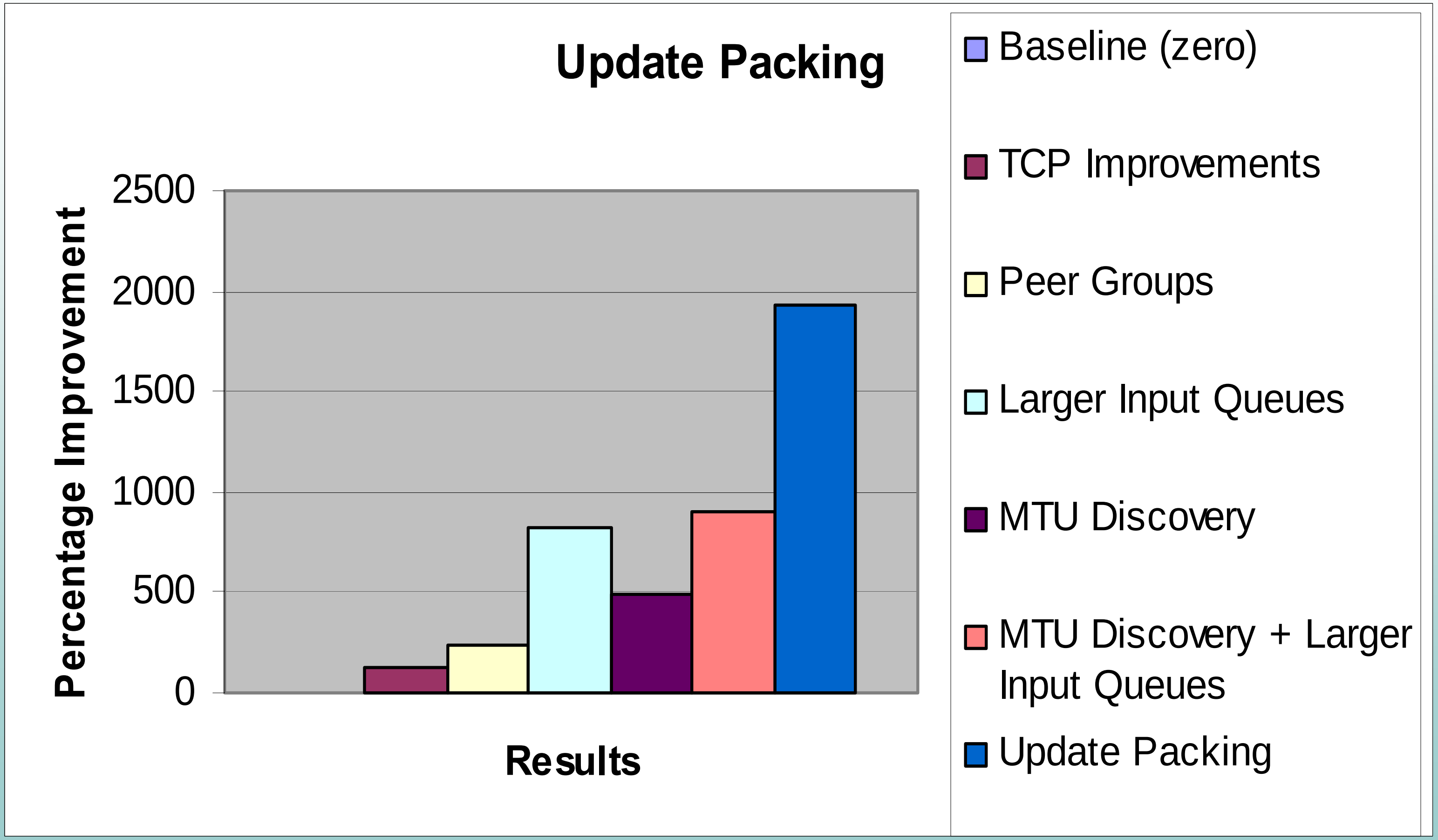
- **Convergence times vary greatly depending on the number of attribute combinations used in the table and on how well BGP packs updates**

BGP Initial Convergence – Update Packing

- **Improved update generation algorithm**
  - **100% update packing – attribute distribution no longer makes a significant impact**
  - **100% peer-group replication – no longer have to worry about peers staying "in sync"**

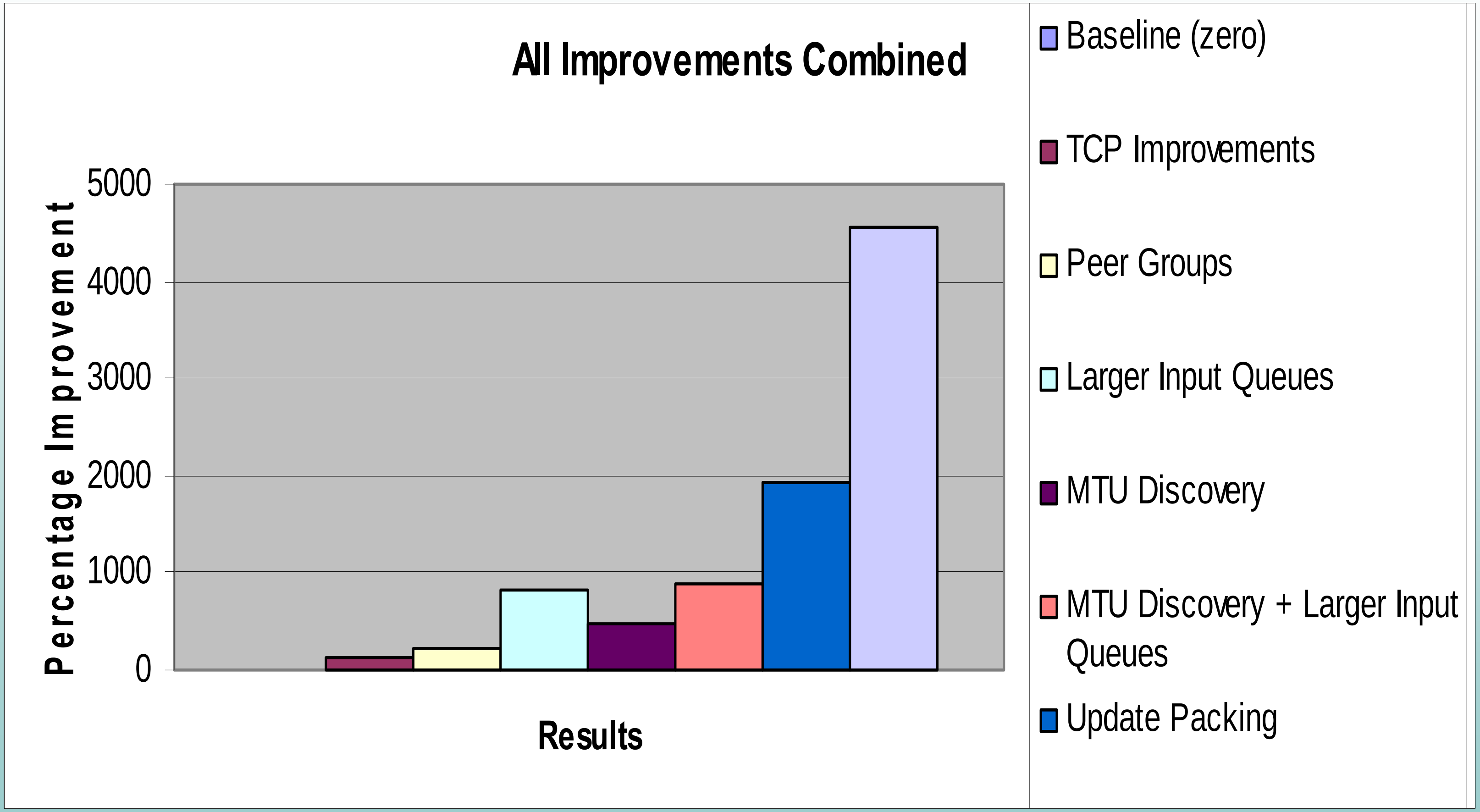
BGP Initial Convergence – Update Packing

Improvement of almost 2000% for 120K routes



BGP Initial Convergence – *Putting It All Together*

- **Update packing + Peer Groups + MTU discovery + Larger input queues = > 4500% Improvement**



BGP Initial Convergence – Summary

- Significant improvements gained just by using configuration options
  - Use peer-groups
  - Adjust input queues
  - Use path MTU discovery
- No need for network upgrades; enhancements are router specific (internal)
  - No interoperability issues

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BGP Peer Groups

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- The main benefits of peer-groups are:

  UPDATE replication: only one UPDATE message is created per peer-group – it is then sent to each individual member.

  Configuration grouping: all the members of a peer-group MUST have the same outgoing policy.

- Any deviation from the peer-group's outgoing policy causes the peer not to be able to be a part of the peer-group

  Results in longer configuration files.

- Peer groups have been shown to significantly improve convergence
- The configuration must be simplified in order to encourage wide deployment of peer groups

BGP Dynamic Peer Groups

- Peer-group members must have the same outgoing policy
- Dynamic peer-groups eases the configuration by internally determining which peers have the same outgoing policy and then generating only one UPDATE for such peers
  - No configuration needed
- Updates are replicated for each member of the group
  - Reduced CPU and memory requirements
  - Faster convergence

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SPF Computation Review

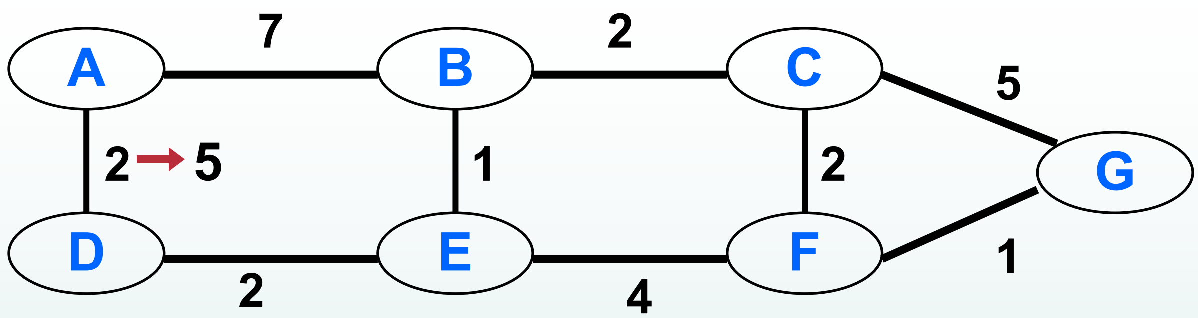
- **Dijkstra algorithm runs by examining each node's LSPs in LSDB**
  - **Build TENT database and Path database (SPT)**
  - **Insert routes into routing tables**
- **SPF computation is triggered when receiving a new LSA**
  - **A new LSA can be received as a result of a link cost change or adding a stub network**
- **The computation usually involves all routers in the same routing area/domain**

SPF Computation

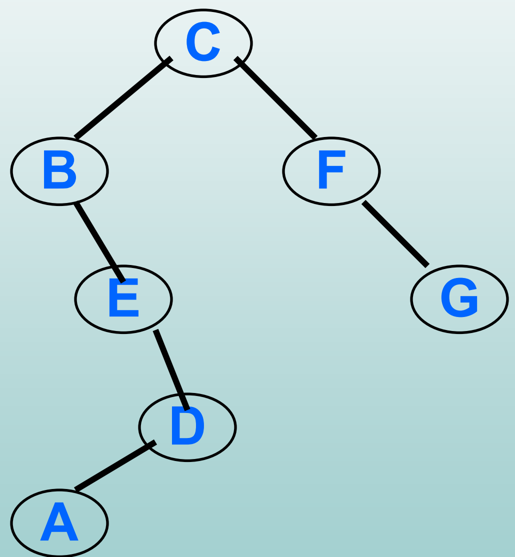
- **Some changes affect only a small part of the SPT, and some do not affect it at all**
- **Thus, it maybe unnecessary to run a “full” SPF computation when there is a topology change, or to run SPF at all when receiving a new LSA**

Shortest Path Tree

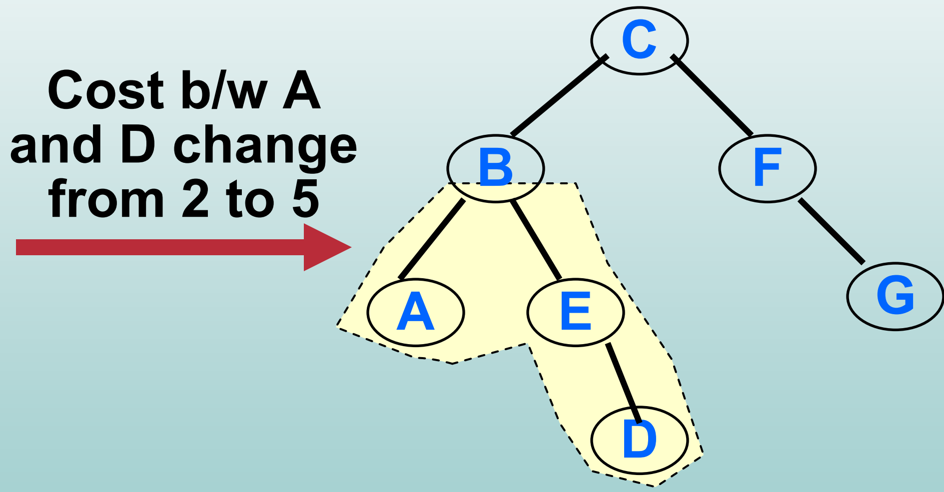
Routing Topology



Shortest Path Tree from node C view



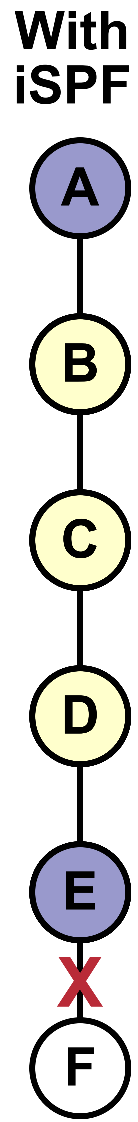
Cost b/w A and D change from 2 to 5



If there is a stub link, changes of the stub link will not have impact on the SPT, but SPF will run anyway

Incremental SPF – Concept

- Incremental SPF (iSPF) allows routers to intelligently determine where the impact of the change is in the SPT and then only re-computes the effected nodes to update the SPT
- As a result, it reduces convergence time by reducing SPF processing time
- Amount of convergence time and CPU cycles saved depend on how many nodes that Dijkstra algorithm would need to examine with and without iSPF
  - The amount of convergence time saved tends to increase as the user moves further from the change



Incremental SPF – Configuration and Deployment

OSPF Configuration

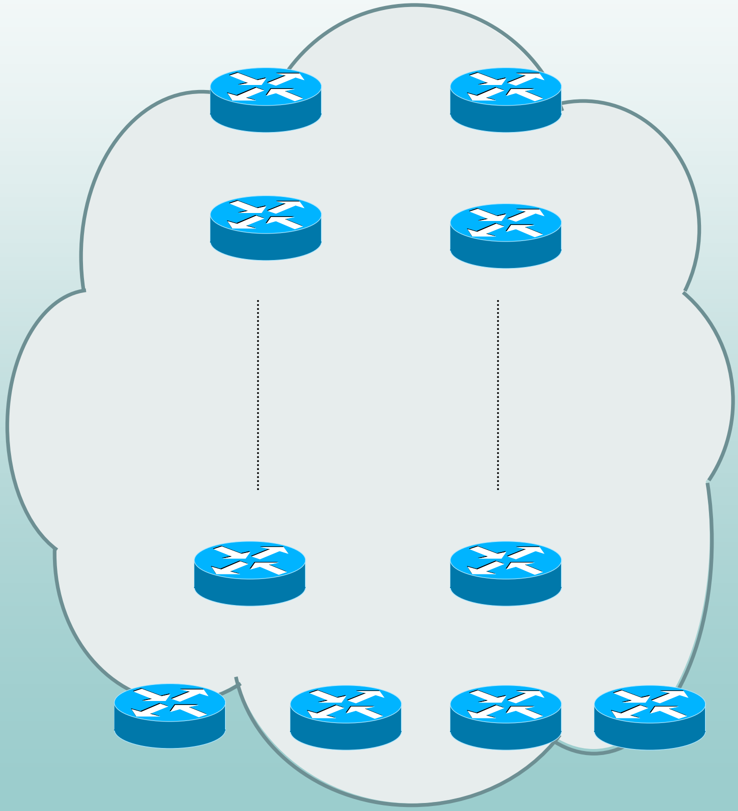
```
router ospf 1
   [no] incremental-spf
```

ISIS Configuration

```
router isis
   incremental-spf [level-1|level-2|level-1-2] [<1-100>]
```

Final parameter [<1-100>] is number of full Dijkstra runs which will be performed before incremental runs begin

Ideal for routing area/domain with large number of nodes and/or stub links



Incremental SPF – OSPF Debug Output

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debug ip ospf spf statistic

Without iSPF

- OSPF: Begin SPF at 188927.520ms, process time 149760ms
- OSPF: End SPF at 188927.572ms, Total elapsed time 52ms
- Intra: 48ms, Inter: 0ms, External: 0ms
- R: 488, N: 758, Stubs: 598
- SN: 0, SA: 0, X5: 0, X7: 0

With iSPF

- OSPF: Begin SPF at 188687.524ms, process time 149612ms
- OSPF: End SPF at 188687.536ms, Total elapsed time 12ms
- Incremental-SPF: 0ms
- Intra: 8ms, Inter: 0ms, External: 0ms
- R: 18, N: 29, Stubs: 22
- SN: 0, SA: 0, X5: 0, X7: 0

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Why Exclude Connected Prefixes?

- In large Internet Service Provider (ISP) networks, IS-IS may be used solely to get the next-hop address for BGP prefixes
- Only the loopback address of the router needs to be in IS-IS
- By default, IS-IS will advertise all connected interfaces
  - Eases configuration for full IS-IS networks
- This results in large IS-IS link-state databases
- Cisco IOS Software Release 12.2(18)SXD adds configuration option to suppress this default behavior

Configuration of IS-IS Excluded Prefixes

- On a per-interface basis:

```
interface ethernet 1/0
            no isis advertise prefix
```

Disable connected prefix advertisement of this interface

- On a per-router basis:

```
router isis
            advertise passive-only
```

Disable advertisement of all connected interfaces except those marked as “passive”

Note: although the same effect can be achieved by using unnumbered interfaces, ISPs prefer numbered interfaces for management purposes

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Fast Hellos – The Problem

- **As customers converge more mission-critical applications onto their IP infrastructure, the ability to quickly reroute around failures is critical**
- **OSPF uses a "HELLO" mechanism to detect failure**
- **HELLOs are sent at <hello-interval time>; If no HELLO seen in <dead-interval time>, traffic reroute begins**
- **Default timers are acceptable for most applications**
- **However, some specialized applications (ie: voice, financial trading, military) may require very aggressive timers**

OSPF Fast Hellos

- **Allows the dead-interval to be set at one second, allowing near instantaneous failure detection**

```
int ethernet 1/0
        ip ospf dead-interval minimal hello-multiplier <3-20>
```

"minimal" sets the dead-interval to one second

"hello-multiplier" determines how many HELLO packets are sent every second

- **Warning: lowering the dead-interval to one second also raises the risk of "false positives"**
- **Customers should verify behavior in a lab that accurately emulates their production environment before deploying**

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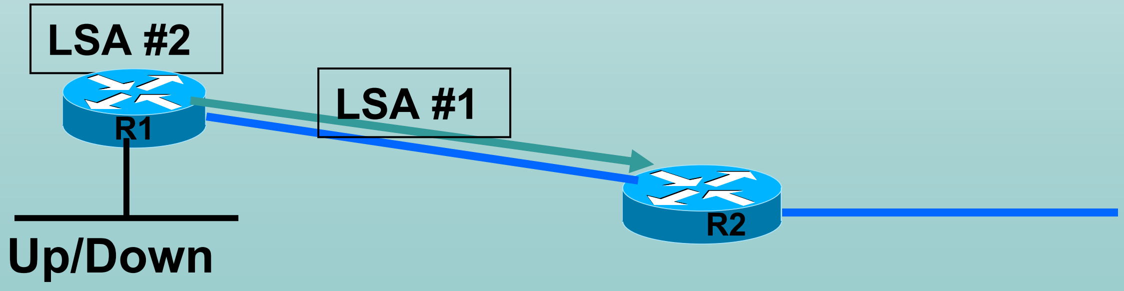
OSPF Event Propagation

- On an OSPF network, after a network event has been detected, an LSA is generated to reflect the change
- LSA is not generated immediately

    OSPF_LSA_DELAY_INTERVAL – 500ms delay (fixed) used when generating Router and Network LSA

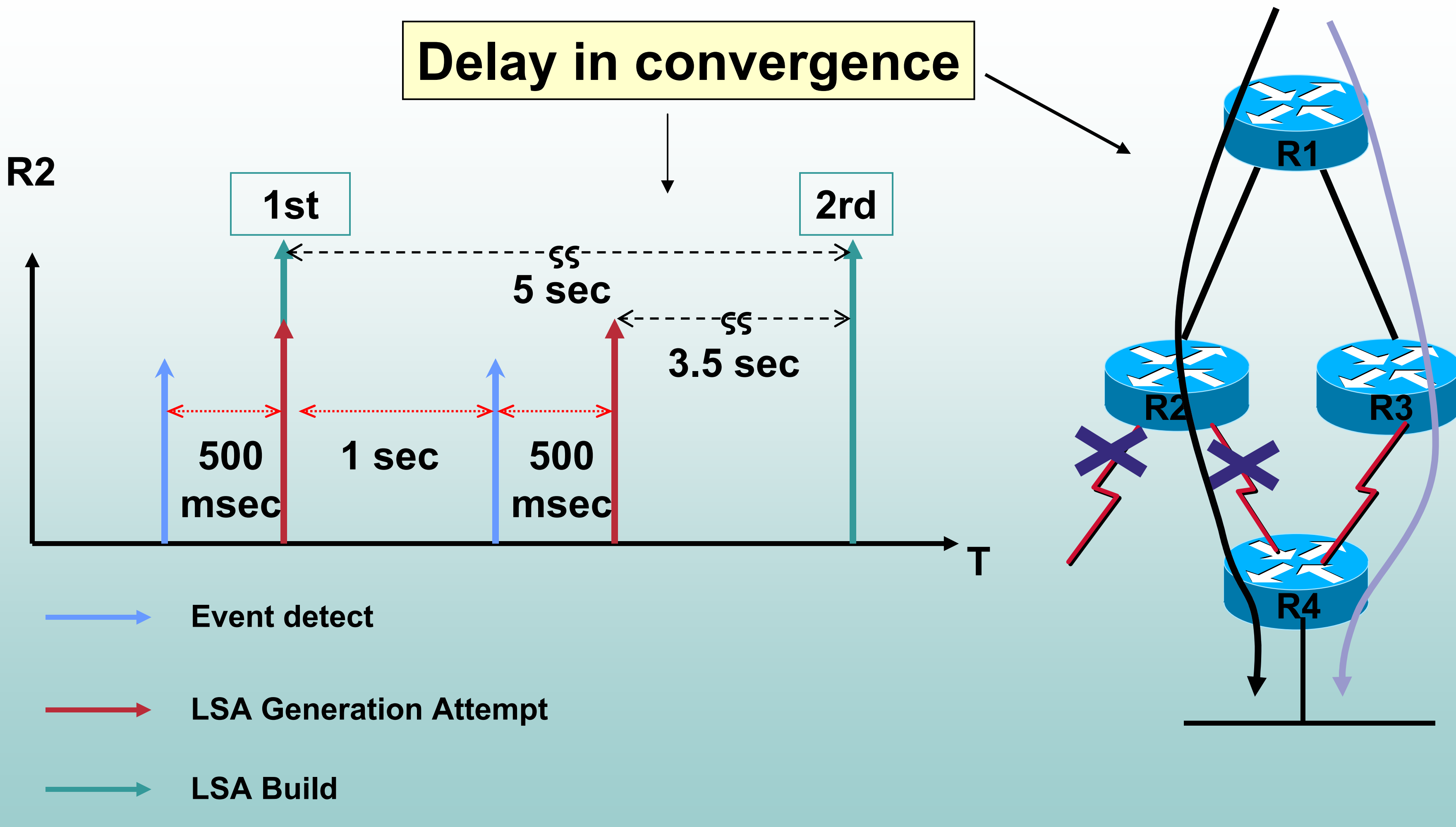
    MinLSInterval – minimum time between distinct originations of any particular LSA; value of MinLSInterval is set to 5 seconds



OSPF Event propagation (Cont.)

- The reason for this delay is to collect any changes that occur during the delay interval and include them all in the new LSA
- This protects routers from generating LSAs too frequently if the interface(s) keeps flapping
- While this timer promotes network stability, it can also delay convergence

Delay in Event Propagation Example



OSPF LSA Throttling

- Enables fast LSA propagation while maintaining stability
- Uses back-off algorithm to generate all LSA as opposed to a constant 5 sec delay
- Introduces three timers (unit: msec)

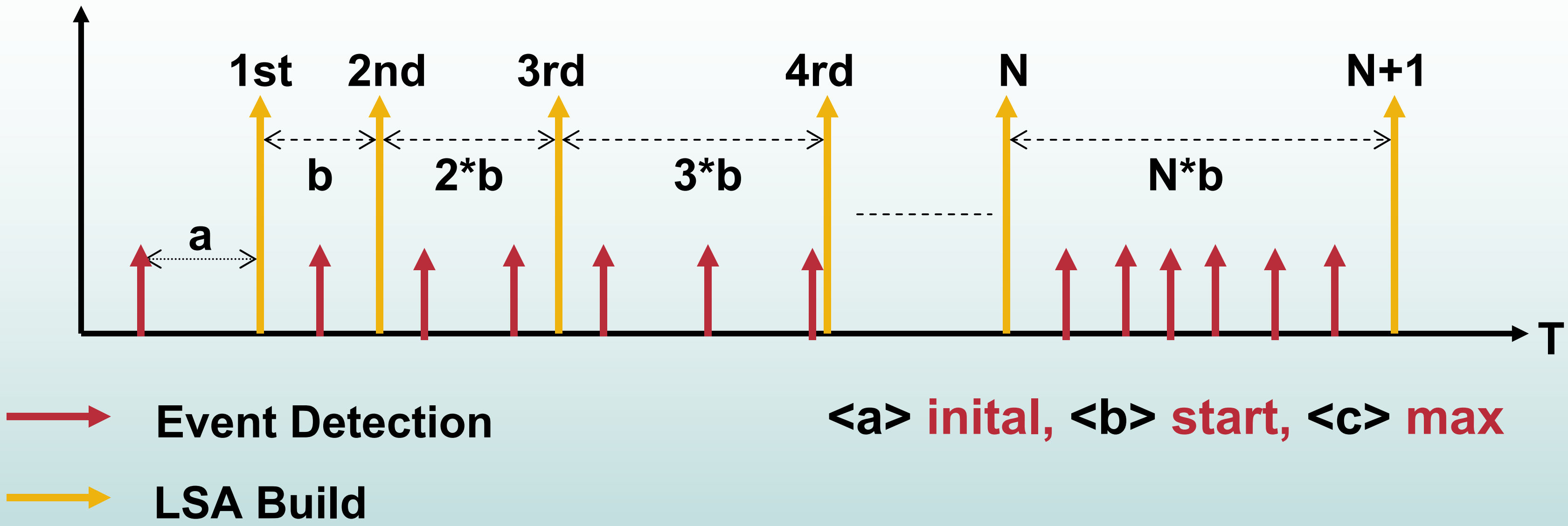
  <initial>: initial delay for generating the first LSA (1-5000)

  <start>: minimum delay while generating LSAs (1-10000); used as a multiplier for consecutive LSA generations

  <max>: maximum wait time while generating LSAs (1-100000)

Throttling Back-off Algorithm and Stability

- **timers lsa throttle all <initial> <start> <max>**

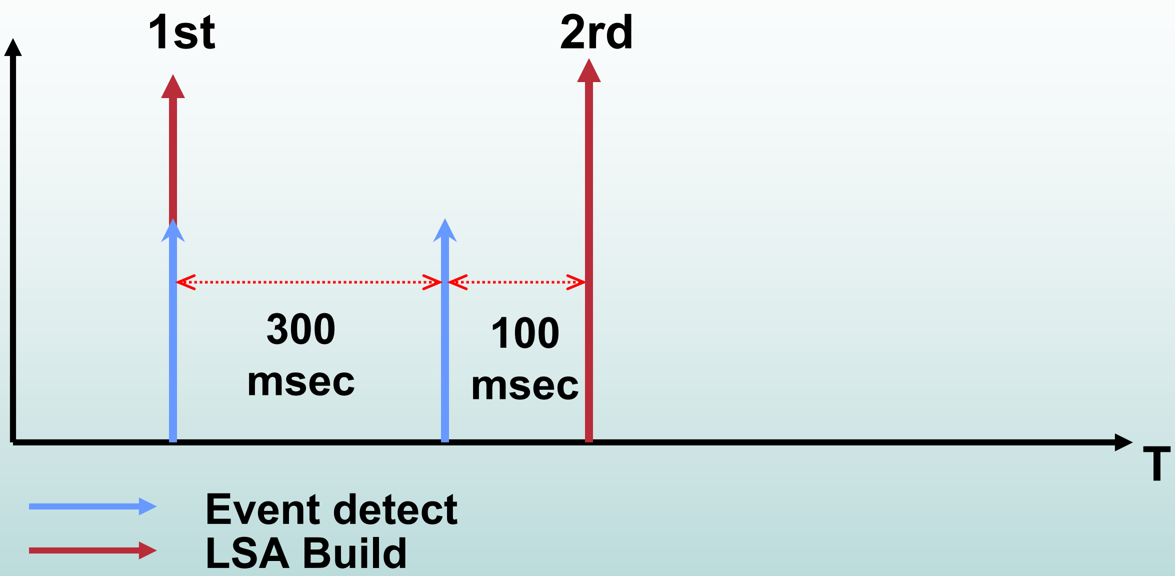


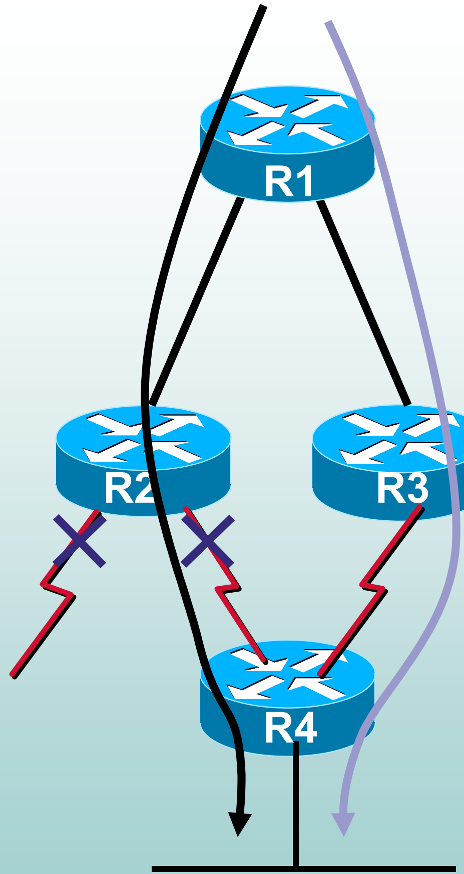
- N*b is less than or equal to max - min[N*b, c]
- Algorithm restart if no SPF event within 2 * c

LSA throttling back-off algorithm absorbs routing-churn effect

OSPF LSA Throttling and Convergence

timers lsa throttle all 100 400 30000





- **LSA throttling allows traffic to switch to the alternative path faster, and**
- **Dampens route-churning during rapid network changes**

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Conclusion

- **Cisco IOS Software Release 12.2(18)SXD incorporates significant routing enhancements from other Cisco IOS Software releases**
- **Enhancements designed to provide the end-user with better:**
  - Convergence optimization
  - Flexibility
  - Ease of deployment

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