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Proposed Extensions to Kerberos-Like Shared-Key Methods for Secure Multicast: Secure IGMP and Coalition Support

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Outline

- Review of current shared-key security for multicast
  - Simple Kerberos-like approach, requiring no router support
  - Basis of GDOI
  - Starting point for Telcordia's security design and implementation
- Secure IGMP
  - Current vulnerabilities (principally denial-of-service attacks)
  - Proposed extensions
- Extensions for coalitions (balance of presentation)
  - Build on existing approach to address the needs specific to dynamic coalitions (limited trust among members, concerns about a single authentication and authorization server, wish for local autonomy in managing authorization policy, scalability, and defense against denial-of-service attacks)
  - Provide similar security functionality to current practice
  - Possible basis for extensions to GDOI or Telcordia implementation

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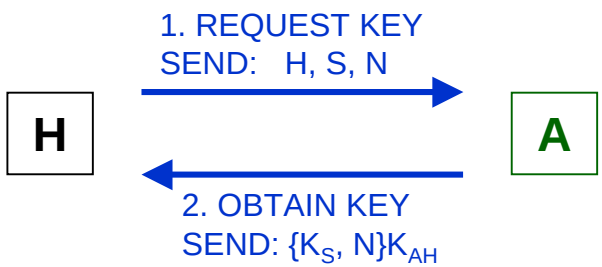
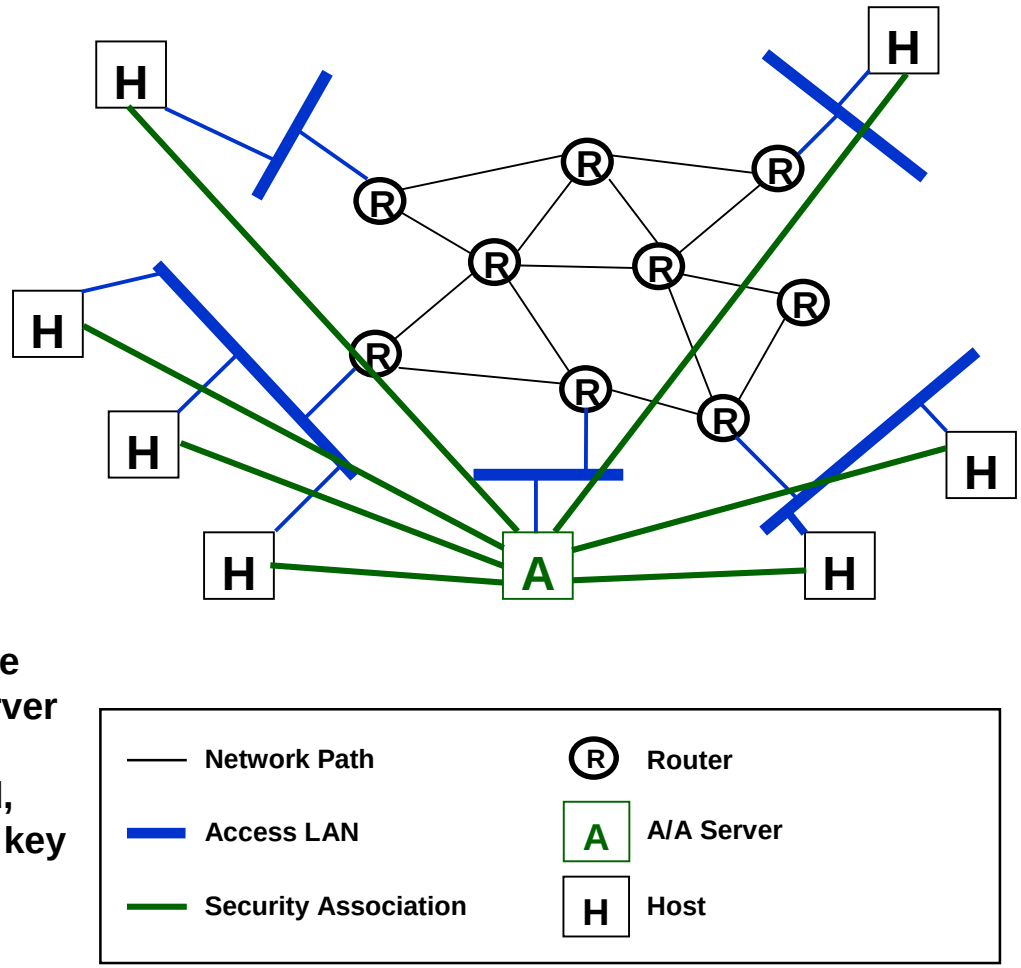
Shared-Key Multicast Security (Current Practice)
Network Picture

Each potential multicast session member must use the existing (green) security association to conduct the following exchange with the authentication and authorization (A/A) server to obtain the multicast session key(s).



The A/A server uses the existing security association to authenticate the potential member. The A/A server then determines authorization. If the potential member is authorized, the A/A server gives it the session key



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Shared-Key Multicast Security (Current Practice)
Who Does What

- Need to establish a (phase 1) security association between the authentication and authorization server and each host in the universe of potential multicast session members
- The authentication and authorization server needs to maintain a database that for each multicast session indicates which of the known hosts are and are not authorized members
- The authentication and authorization server must also maintain the current shared key for each multicast session
- For each authorized session member, the authentication and authorization server will give it the current shared multicast session key on demand
- Multicast senders use this key to encrypt data before multicasting
- Multicast receivers use this key to decrypt incoming data (which also provides limited authentication of the sender)

Shared-Key Multicast Security (Current Practice) Rekeying

- The three reasons for rekeying a multicast session
  - On Member Join
    - Rekey to stop new member X from decrypting traffic from before X joined
    - Implementation:
      - Multicast new key to current members encrypted with current key
      - Give new key to X on point-to-point secure connection
  - On Expiration of Multicast key
    - Rekey to limit amount of data encrypted with old key
    - Implementation:
      - Multicast new key to current members encrypted with current key
  - On Member Ejection
    - Rekey to stop departing member X from decrypting new traffic
    - Implementation (two choices):
      - Require each member to obtain new key in a one-to-one interaction with the authentication and authorization server
      - Multicast new key encrypted with an existing key, using some fancy method, like tree-structured keys, to hide the new key from the ejected member

Security Goals
Definitions

- **Confidentiality:** Enemy can't read message
- **Integrity:** Enemy can't change message
- **Authentication**: Claimed sender equals actual sender
- **Access control:** Only authorized parties can participate
- **Dynamic authorization:** Allow change in authorized parties
- **Non-repudiation:** Recipient can prove what messages it got
- **No denial of service:** No interference by un-authorized parties

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Satisfaction of Security Goals
Shared-Key End-to-End Kerberos as Baseline

	KERBEROS SHARED KEY	TREE OF SHARED KEYS	MAC CODES OR LOCAL KEY SCOPE	PUBLIC KEYS	SECURE IGMP PROTOCOL
CONFIDENTIALITY	√				
INTEGRITY	√ NEED REPLAY DEFENSE				
AUTHENTICATION	X SEND BY ANY GROUP MEMBER		√	√	√?
ACCESS CONTROL	√				
DYNAMIC AUTHORIZATION	½ JOIN: O(1) LEAVE: O(N)	√ JOIN: O(1) LEAVE: O(log N)			
NON-REPUDIATION	X			√	
NO DENIAL-OF-SERVICE	X				√

DELTA FROM BASIC KERBEROS SHARED KEY

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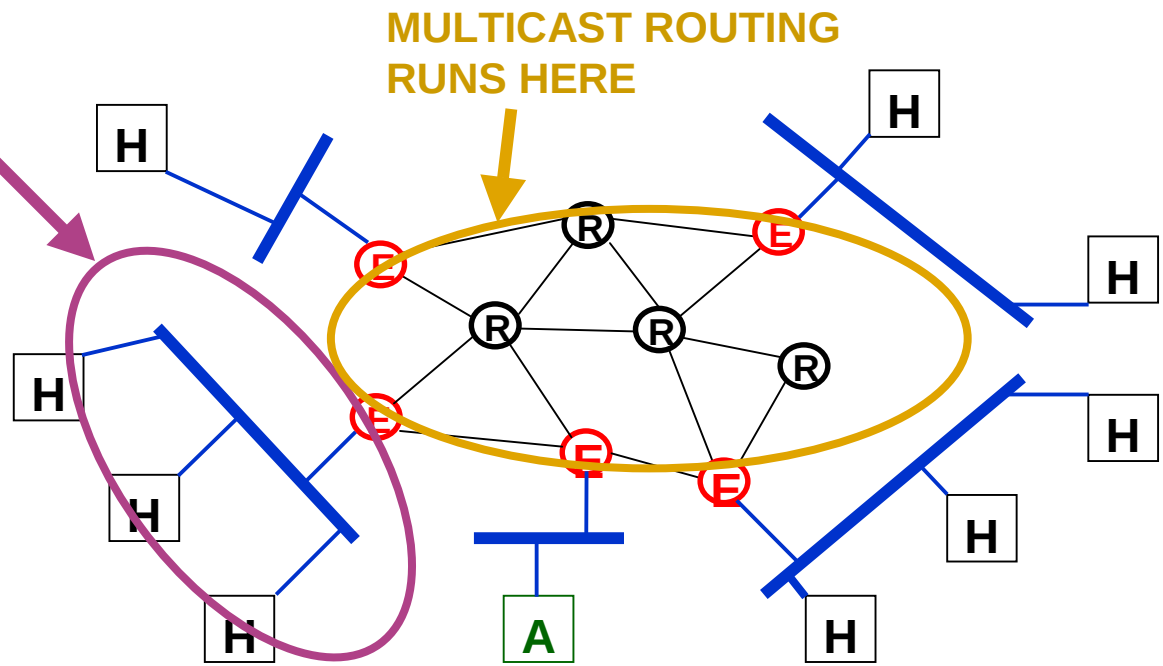
IGMP
Network Picture

Function	IGMP V1	IGMP V2	IGMP V3
QUERY	Yes	Yes	Yes
REPORT	Yes	Yes	Yes
LEAVE		Yes	Yes
Granularity	Group	Group	Group & Source



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IGMP
Security Vulnerabilities

- Denial of service
  - Bogus receiver wastes bandwidth by requesting to join a group whose traffic it can't read
  - Bogus receiver disrupts service on LAN by sending IGMP leave messages
  - Bogus sender floods multicast group, wasting bandwidth even if receivers can identify the extra packets as invalid
- Leaking information
  - Some extra exposure to traffic analysis
  - Some extra access to encrypted text for cracking attacks

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How to Secure IGMP

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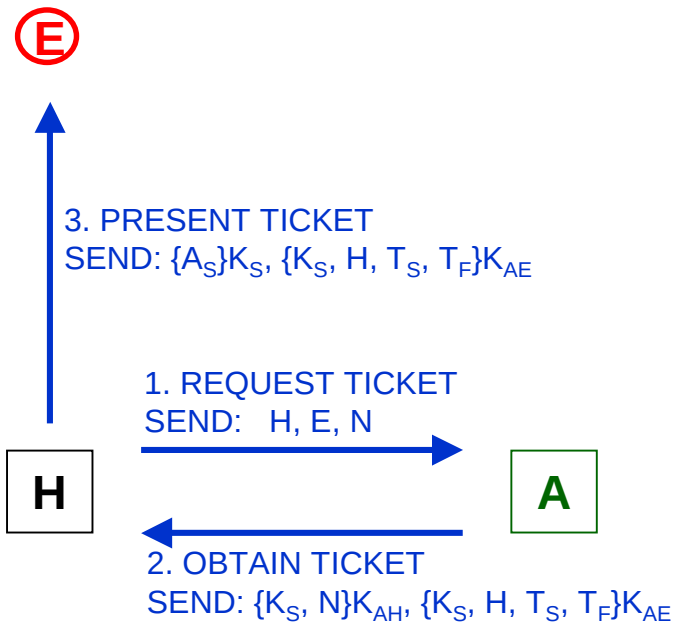
Secure IGMP

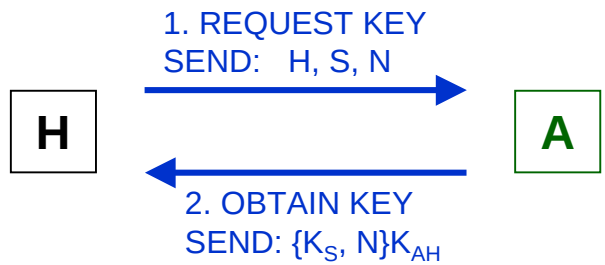
A/A Protocols a la Kerberos (both needed)

Obtaining a Ticket to present to edge router in secure IGMP



Obtaining a Session Key for use with multicast session data

Each session member must do the following:



Key:

H: Hosts
A: Authentication Server
E: Edge Router

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Securing IGMP

IGMP currently has no security support…

IGMP Current Functions

- Enables an edge router to know if there exists one or more hosts on its subnet that wish to receive a given multicast group
- Provides edge router with inexact knowledge of which hosts are receiving a given group
- Does not give count of number of recipients
- No security functionality

IGMP Absent Functions

- Enabling receiver authentication to edge router
- Prevent bandwidth use by unauthorized receivers
- Support of authenticated membership requests for senders
- Prevent bandwidth use by unauthorized senders
- Give edge routers exact knowledge of group membership on local subnetwork

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Securing IGMP
Four Options

Capabilities	Options for Secure IGMP (details follow)			
	Option 0	Option 1	Option 2	Option 3
End-to-end encryption of multicast session, with key given only to authorized members	√	√	√	√
Receivers demonstrate authentication and authorization to edge routers		√	√	√
Senders demonstrate authentication and authorization to edge routers			√	√
Edge routers have exact knowledge and control of group members on subnet				√

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Securing IGMP
Option 0 (Baseline)

Description: No change to IGMP. Rely on multicast session key(s) for security. Each sender and receiver authenticates itself to the A/A server and (if authorized) obtains and uses the session key

- Bogus receivers can obtain traffic to do code breaking and traffic analysis
- Bogus receivers can launch limited DOS attacks by requesting groups for which they are not authorized
- Bogus senders can launch significant DOS attacks by sending garbage traffic
- Hosts on same LAN may share same session key, edge router has inexact knowledge of local group membership
- Simple, no code changes to routers or host IGMP implementations, could be sufficient in some applications

Securing IGMP
Option 1

Description: Receiver must demonstrate to edge router that it is authorized. Edge router accepts report and leave messages only from authorized receivers. Also, Option 0 functionality is provided

- Bogus receivers cannot obtain traffic to do code breaking and traffic analysis UNLESS they are on the same subnet as a legitimate receiver (limitation seems inherent in shared LANs)
- Eliminates spurious traffic requests by bogus receivers
- Eliminates spurious leave messages
- Bogus senders can launch significant DOS attacks by sending garbage traffic
- Hosts on same LAN may share same session key, edge router has inexact knowledge of local group membership

Securing IGMP
Option 2

Description: Sender must demonstrate to edge router that it is authorized. Option 0 and option 1 functionality is also provided

- Because the access LAN is shared, the edge router must authenticate the source of each packet that is sent to a multicast group
- Bogus receivers cannot obtain traffic to do code breaking and traffic analysis UNLESS they are on the same subnet as a legitimate receiver (limitation seems inherent in shared LANs)
- Eliminates spurious traffic requests by bogus receivers
- Bogus senders cannot send garbage traffic on the multicast tree
- Hosts on same LAN may share same session key, edge router has inexact knowledge of local group membership

Securing IGMP
Option 3

Description: All interaction between a sender and an edge router is over an IPsec tunnel. All interaction between a receiver and an edge router is over an IPsec tunnel. Sender must prove to edge router that it has authorization. Receiver must prove to edge router that it has authorization. A/A server still useful for authorization. Also, Option 0 functionality is still provided

- If shared session keys are used, prevents a non-member sender from reading the traffic on this group
- Equivalent benefit regarding senders could be obtained by using per sender session keys
- Care needs to be taken to avoid crypto attacks based on having multiple encryptions of the same content
- Seems to conflict with the use of shared access networks

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Proposed Extensions to Support Coalitions

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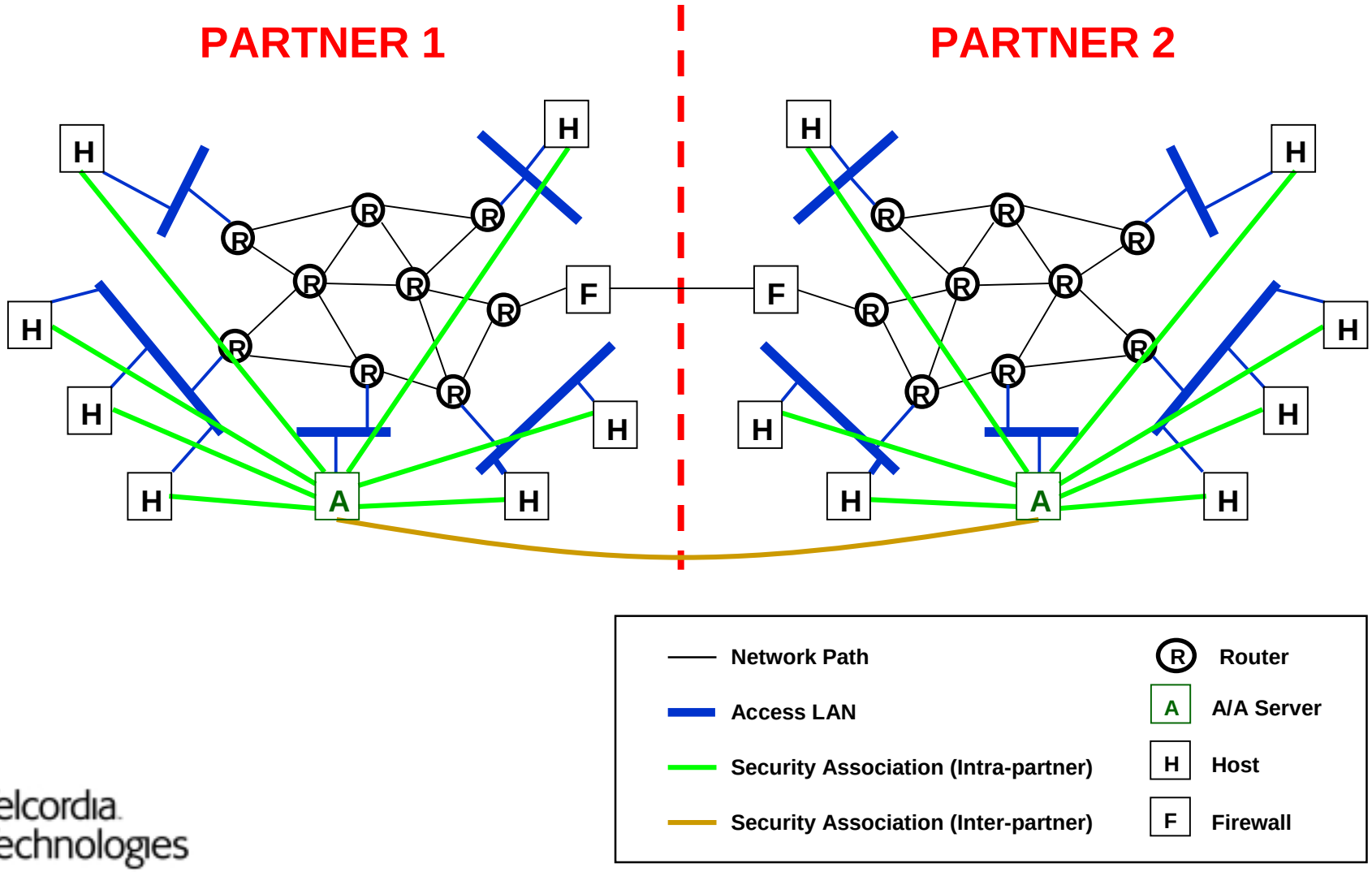
Design Goals – Secure Coalition Networking with More Local Autonomy

- Operate with limited router or firewall support (at network borders)
- Use shared and partially shared session keys distributed by A/A (Authentication/Authorization) servers
- *Each coalition partner has its own A/A server*, with limited trust among A/A servers of the coalition partners
  - Each coalition partner manages its own list of authorized session members for each multicast session
  - Each coalition partner authenticates its own members, even in shared sessions
  - Each coalition partner chooses keys for use within its own network, with some re-keying at network borders
- Some multicast sessions are shared among coalition members and some are not
  - A coalition member controls which of its sessions are shared
  - Firewall support may limit scope of non-shared sessions (configuration issue)
- Potential extension to GDOI or Telcordia Hierarchical Application Secure Multicast (HASM) implementation
- Design requires either a lead coalition partner (to generate shared key) or Diffie-Hellman method for A/A servers to agree on session key

Shared-Key Multicast Security (Extension)
Coalition Network Picture



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Shared-Key Multicast Security (Extensions)
Initial Security Associations Needed

- Within a coalition partner
  - There must be a security association (shared key) between the authentication and authorization server (for that partner) and each potential multicast participant located within that partner's network
  - These security associations are shown in green in the network picture
- Among coalition partners
  - Each pair of coalition partners must establish a security association (shared key) between their authentication and authorization servers
  - These security associations are shown in mustard in the network picture

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Shared-Key Multicast Security (Extensions)
Behavior of Multicast Session Members

- Go to local authentication and authorization server to obtain the shared key for the multicast session, plus the authentication key
- Use these keys to encrypt and authenticate session messages, authentication is only at granularity of coalition partner
- Accept new multicast session keys that are broadcast with the currently valid multicast session key
- In short, act almost the same as in the un-extended version, except for the added authentication operations

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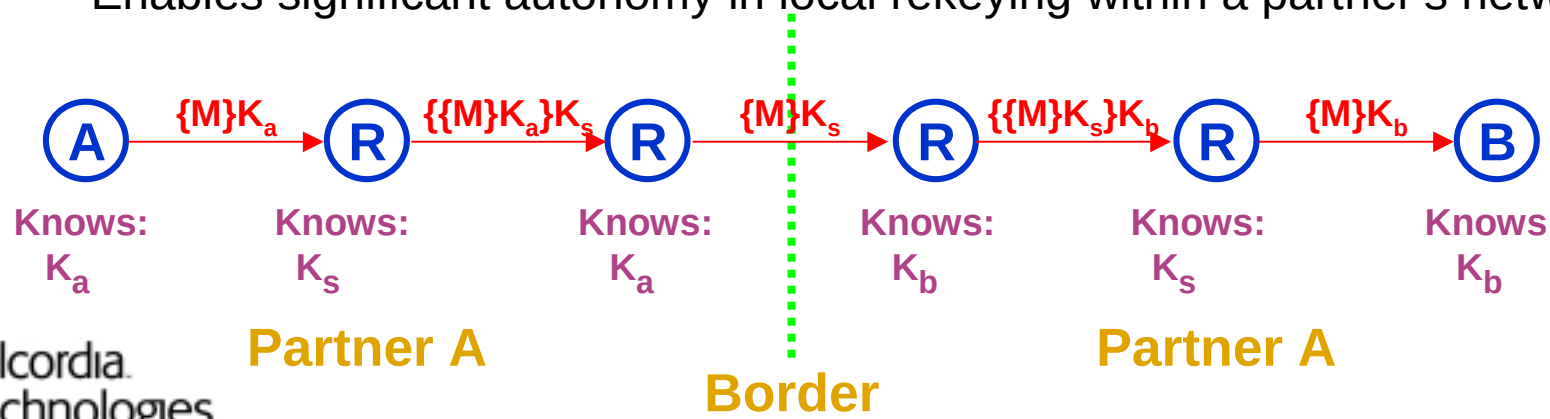
Switching Keys at Administrative Borders in Coalition Networks – Solution 1

- Requires Commutative Encryption Using Shared Keys
- Enables switch of key within the network, without producing cleartext in the network or having any single point of attack
- Requires a pipeline of two network elements at border to perform the key change
- Coalition partner A uses K_a within its network, coalition partner B uses key K_b within its network, etc. (keys assigned by local A/A server only)
- All coalition partners use K_s for inter-partner traffic (key distribution for K_s is coordinated among all of the A/A servers of all partners)
- Enables significant autonomy in local rekeying within a partner's network



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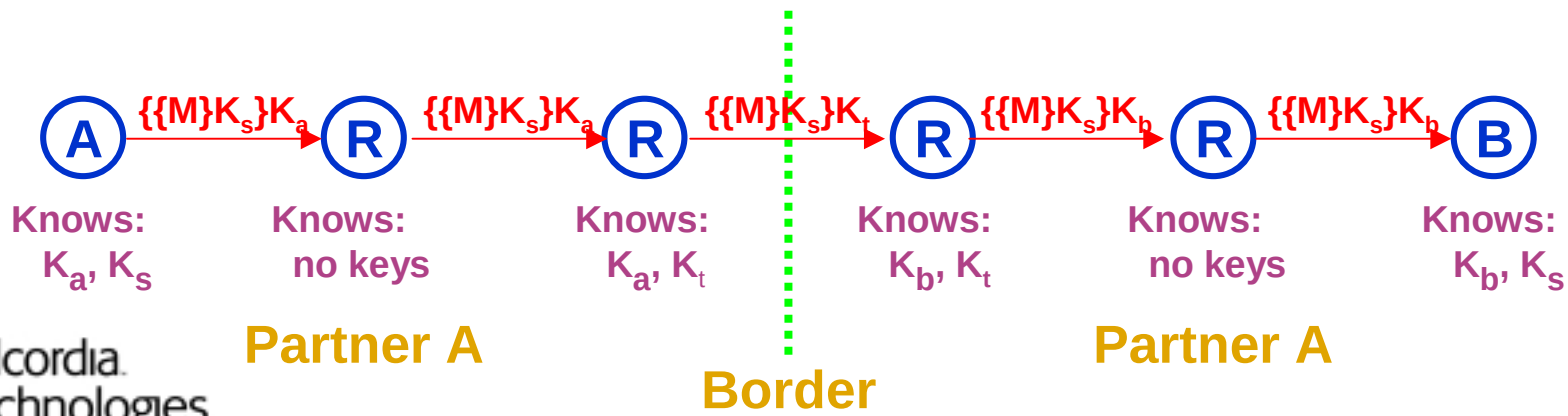
Switching Keys at Administrative Borders in Coalition Networks – Solution 2

- Requires double encryption, but works with any cryptosystem
- Enables switch of key within the network, without producing cleartext in the network or having any single point of attack
- Requires only one network element at border to perform the key change
- Coalition partner A uses K_a within its network, coalition partner B uses key K_b within its network, etc. (keys assigned by local A/A server only)
- Edge routers use K_t for traffic among partners
- All coalition partners use K_s for inter-partner traffic (key distribution for K_s is coordinated among all of the A/A servers of all partners)
- Enables significant autonomy in local rekeying within a partner's network



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Shared-Key Multicast Security (Extensions)
Behavior of Multicast Session Members

- Go to local authentication and authorization server to obtain the global (solution 2 only) and local shared keys for the multicast session
- Use these keys to encrypt (only the local key is needed in solution 1, both are needed in solution 2)
- Accept new local multicast session keys that are broadcast with the currently valid local multicast session key
- Accept new global multicast session keys that are broadcast with the currently valid global multicast session key
- In short, act almost the same as in the un-extended version, except for the use of multiple keys

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Current Status

- Support for coalitions
  - Implementation available, no Diffie-Hellman
- Secure IGMP
  - Design only

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Extra Slides

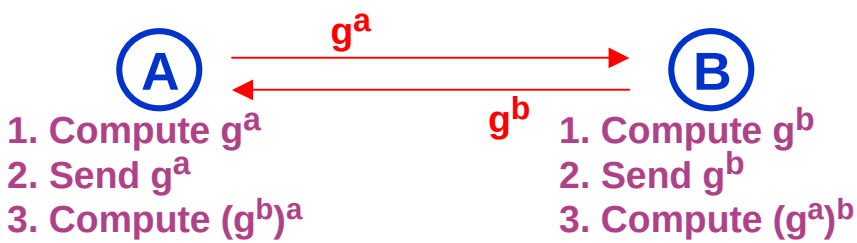
Shared-Key Multicast Security (Current Practice)
Authentication of Multicast Data

- How multicast session members use the session key for encryption and authentication
  - Given message M and session key K_S:
    - Compute $\{M\}K_S$
    - Send $\{M\}K_S$
  - Message can be generated or decrypted by any party with the session key
- Authentication functionality provided:
  - Any session member can authenticate that a message came from an authorized session member, but not which one
- Extend authentication functionality using multiple keys for generating MAC codes (with each key shared by a different subset of members)
  - MAC codes are key-specific secure hashes of the message
  - Given message M and secret authentication key K_A
    - Compute MAC(M, K_A)
    - Send M, MAC(M, K_A)
  - Code can be checked by anyone with the authentication key, furnishing a proof that the message authentication code was generated by someone who knows the particular authentication key

Existing Cryptographic Mechanisms (Primitives Used in Proposed Extensions)

Dynamic Generation of a Shared Key
2-Party Protocol (due to Diffie and Hellman)

- Required initial information (shared by both parties):
  - *p* is a prime, all computations are done in GF(p), meaning mod *p*
  - *g* is a generator mod *p,* meaning $\forall x \exists y$ such that $x = g^y \bmod p$
- Each participant contributes to the shared key
  - Participant A, picks value *a* and participant B picks value *b*
  - Shared key is $g^{ab} \bmod p$
- Diffie-Hellman messages sent in the clear, but only the two participants learn the shared key
  - Knowledge of *p*, *g*, g^a, and g^b does not enable efficient computation of g^{ab}



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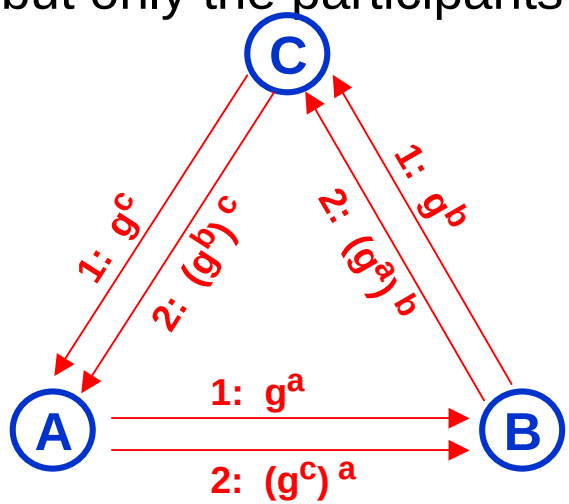
Dynamic Generation of a Shared Key
N-Party Protocol (due to Diffie and Hellman)

- Required initial information (shared by all parties):
  - *p* is a prime, all computations are done in GF(p), meaning mod *p*
  - *g* is a generator mod *p,* meaning $\forall x \exists y$ such that $x = g^y \bmod p$
- Each participant contributes to the shared key
  - Participant A, picks value *a,* participant B picks value *b,* participant C picks value *c, . . .*
  - Shared key is $g^{abc} \bmod p$ (when there are three participants)
- Diffie-Hellman messages sent in the clear in N rounds of communication, but only the participants learn the shared key



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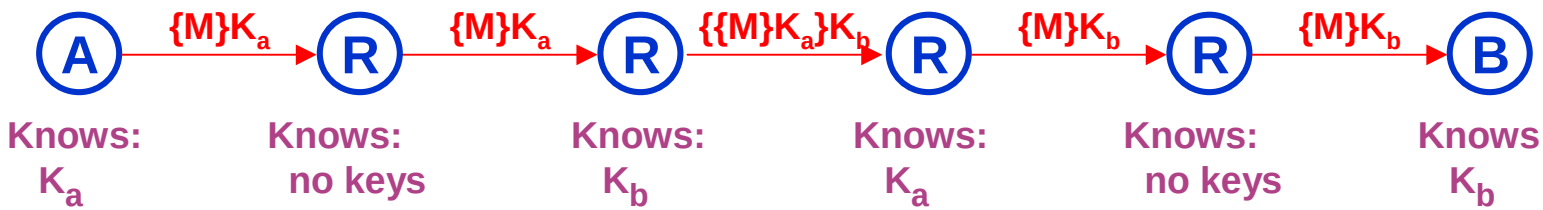
Commutative Encryption Using Shared Keys

- Desired property is $\{\{M\}K_a\}K_b = \{\{M\}K_b\}K_a$
- Encryption algorithm with this property:
  - Use cryptographically secure pseudo-random number generator to produce the pad for one-time pad encryption
  - Encryption commutes because exclusive or (the operation used in one-time pads) commutes
- Use to enable switch of key within the network, without producing cleartext in the network or having a single point of attack



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Shared-Key Multicast Security (Extensions)
Changed Role for A/A Servers 1 of 2

- Each server maintains the following information in its Authorization database for each multicast group
  - Which local hosts (i.e. hosts within this coalition member) belong to the multicast group
  - Which other coalition members may have hosts in the multicast group (just the coalition member (e.g. USA) is maintained, not the identity of individual hosts)
  - The identity of the coalition partner who is the lead for the multicast group
    - The lead for a multicast group must be unique
    - The lead for a multicast group must be a authorized to be in the group
  - The current shared key for the multicast group
  - A partner-specific key for authentication (e.g., generating MAC codes)
    - e.g., 5 partners: O(N^2): 25 keys

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Shared-Key Multicast Security (Extensions)
Changed Role for A/A Servers 2 of 2

- A valid request for the session key must come either from a host within this coalition partner or from a peer A/A server (in a different coalition partner)
- If the request is from a host in the local network, do the following
  - Authenticate host
  - Determine whether host is authorized
  - If this is the lead partner for the group, return session key and MAC key, encrypted with shared secret
  - If this is not the lead partner for the group, request session key from A/A server from lead partner, return that session key plus local MAC key, encrypted with shared secret
- If request is from a peer A/A server, do the following
  - Authenticate A/A server
  - Determine whether A/A server is authorized and this is the lead partner
  - Return the session key, encrypted with the shared secret

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Shared-Key Multicast Security (Extensions)
Network Support

- All of this can operate with no network support in routers and firewalls
- One vulnerability is that it opens multicast groups that should be private to a single coalition member to tampering by other coalition members, including
  - Generating garbage traffic
  - Receiving encrypted traffic
- Improved security can be obtained by *configuring firewalls to pass only that multicast traffic from groups that involve at least two coalition members*
  - e. g., Set policy via service grammar on firewalls
- Following are additional security measures that can be taken with support in some network elements, possibly border routers or firewalls

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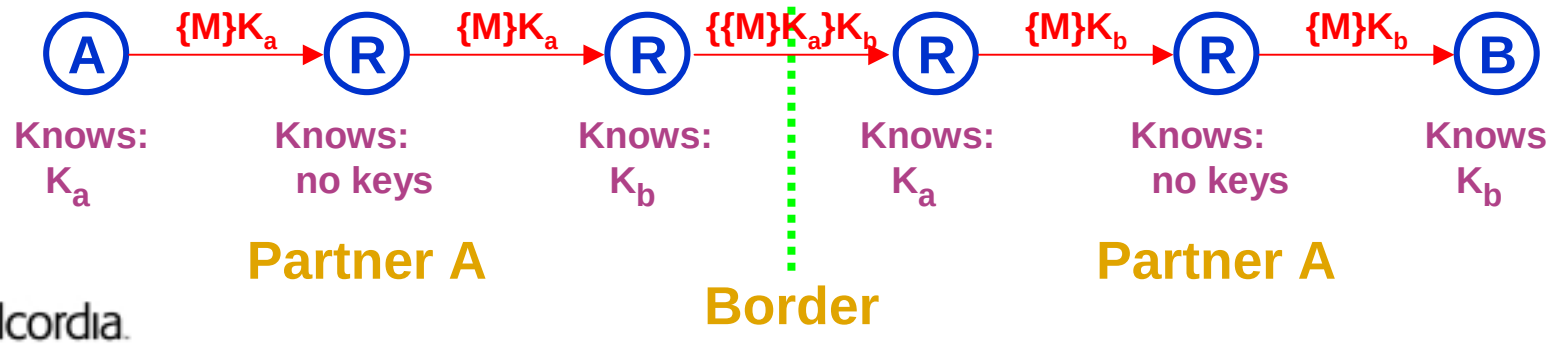
Switching Keys at Administrative Borders in Coalition Networks – Solution 0

- Requires Commutative Encryption Using Shared Keys
- Enables switch of key within the network, without producing cleartext in the network or having any single point of attack
- Coalition partner A uses K_a within its network, coalition partner B uses key K_b within its network, etc.
- Main deficiency is still that each coalition partner must have knowledge of all keys – deficiency is addressed in the next two solutions
- Note: only portions of the network are shown, R is a router, A and B are hosts



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Multicast Security (Solutions 1 &2)
Required Behavior of A/A Servers 1 of 3

- Changed requirements are highlighted in blue
- Within a coalition partner
  - need a security association (shared key) between the local A/A server and each potential multicast participant (host)
  - Need a security association (shared key) between the local A/A server and each network element that must perform either encryption of decryption of multicast traffic
- Each pair of coalition partners must have a security association (shared key) between their A/A servers

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Multicast Security (Solutions 1 &2)
Required Behavior of A/A Servers 2 of 3

- Each A/A server maintains the following information in its Authorization database for each multicast group
  - Which local hosts (i.e. hosts within this coalition member) belong to the multicast group
  - Which network elements are authorized to perform encryption and decryption (and for solution 1, which key the element is authorized to use)
  - Which other coalition members may have hosts in the multicast group (just the coalition member (e.g. USA) is maintained, not the identity of individual hosts)
  - The identity of the coalition partner who is the lead for the multicast group
    - The lead for a multicast group must be unique
    - The lead for a multicast group must be a authorized to be in the group
  - The current shared key for the multicast group and the local key for the group (key specific to this partner)

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Multicast Security (Solutions 1 &2)
Required Behavior of A/A Servers 3 of 3

- A valid request for the session key must come from
  - A host within this coalition partner
  - A peer A/A server (in a different coalition partner)
  - A network element within this coalition partner
- If the request is from a host in the local network, do the following
  - Authenticate host and verify that host is authorized
  - If this is the lead partner for the group, return global (solution 2 only) and local session keys, encrypted with shared secret
  - If this is not the lead partner for the group, request global session key from A/A server at lead partner, return that global session key plus local session key, encrypted with shared secret (global key needed only in solution 2)
- If the request is from a local network element, do the following
  - Authenticate network element and verify that it is authorized
  - Determine what key the network element is authorized to have, obtain key as above (either locally or from peer A/A server) and return encrypted key
- If request is from a peer A/A server to the lead partner, do the following
  - Authenticate A/A server and verify authorization
  - Return the global session key, encrypted with the shared secret

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