Key Management for Secure Multicast in Hybrid Satellite Networks

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Problem Statement

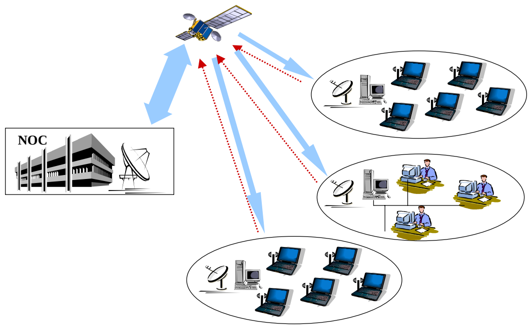
To design a framework for multicast key management in hybrid satellite networks.
• Satellites are attractive media for group data delivery, due to wide coverage and broadcast capabilities. Expected to be major component of future wide-area broadband multicast.
• Commercial viability of broadband multicast applications require that the data be accessible only to authorized receivers – achieved by data encryption.
• Encryption requires secure and efficient methods to distribute the encryption/ decryption keys to all the group members. Existing group key management protocols do not scale well when applied as is to large dynamic groups in wide-area networks.

We analyze current group key management protocols and design a framework for secure and scalable key management for hybrid satellite networks that have terrestrial Ethernet LANs interconnected by ATM-based satellite channels.

Key Management Review

• *Key management* refers to the generation, distribution and update of group encryption/decryption keys.
• A secure group key management protocol should ensure *key confidentiality*, *forward* and *backward access control*, and *key independence*.
• Protocols should be scalable, robust, have low overhead in communication, processing and storage.
• Proposed designs for group key management are either:
  • centralized - schemes requiring a group controller (GC) for key generation, such as KPS, Broadcast Encryption, Secure Lock, GKMP, CAS, LKH, or,
  • distributed – group members collaborate to generate the keys: GDH, Iolus.
Some designs are combinations of both – HFK, variations of LKH.

Network Topology



• Multiple terrestrial LANs that have one or more satellite terminals connected to them; satellite has ATM switching functionality, no IP.
• Proposed a multicast routing framework for the hybrid satellite network [1]. PIM-SM is used for IP multicast in the terrestrial Ethernet LANs; ATM with MARS architecture for multicast over the satellite links.
• One or more satellite terminals in each terrestrial LAN act as Rendezvous Point (RP) for the multicast groups within its LAN; the MARS is located at the NOC.

Proposed Framework

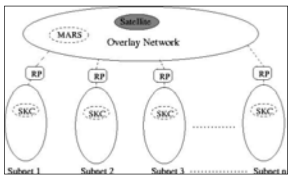
Security Considerations

• Requirement: data privacy for multicast groups in the satellite network.
• Groups varying widely in size, high member dynamics.
• Independent domains with different security policies.
• Simultaneous reliable delivery to all domains an issue - channel errors due to rain fade in geostationary satellite.
• Objective: ensure keys are delivered correctly to maximum members possible.
• Primary metric: Communication overhead, due to high latency in satellite links.

Therefore: design a framework that minimizes communication over the satellite links, to reduce delay in group initialization and key updates and error conditions.

Solution: Tiered Tree Framework

• Hierarchical network topology – *independent* terrestrial subnetworks/domains, with the satellite channels forming an *overlay*.
• Divide key management into two levels. Use logical key trees in each level.
• Global RP Tree in overlay, local SN Tree in each subnetwork.



Logical Grouping

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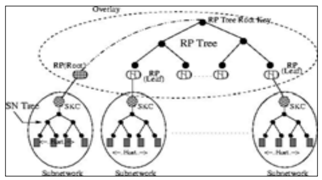


Tiered Tree Framework

Trust Model

• MARS – Performs access control for domains, maintains database of member domains, Certificate Authority. Not authorized to read data traffic.
• RP – securely transmits/receives multicast traffic. Not trusted to read data traffic.
• Hosts: encrypt/decrypt application data.
• Subnetwork Key Controller (SKC): manages group keys in subnet. Performs access control for subnet members.

RP Tree

• RPs are at the leaves of the RP tree.
• Root RP dynamically selected by MARS based on group policy – *earliest to join*.
• Security additions to MARS messages, MARS table.
• At no point does MARS obtain the traffic.

SN Tree

• LAN hosts are leaves of SN Tree - stores all keys on path from its leaf to root.
• Each host also given long-term *datahiding key*, common to all group members across all subnets.
• Local RP gets only the session key from the SKC.

Secure Data Transmission

• Source encrypts twice: datahiding key + local session key.
• RP partially decrypts using local session key. Cannot decrypt further without the datahiding key. Re-encrypts using the RP Tree session key; transmits to remote subnets over satellite links.
• Remote RP decrypts partially using RP Tree key. Re-encrypts with local session key and forwards along local multicast tree.

Communication/Storage Cost

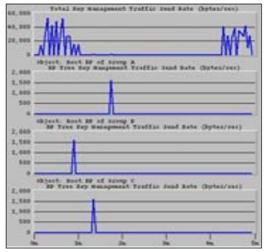
	Total Cost
Tree setup	$(n_1-1)k_p + \frac{d_1(n_1-1)}{d_1-1}k_s + n_1\left(\left(n_2+\frac{d_2(n_2-1)}{d_2-1}+1\right)k_s\right)$
Member join to existing group in subnet	$(d_2h_2+2)k_s$
Adding a subnet to existing group	$k_p+(d_1h_1+1)k_s+\lceil\left(n_2+\frac{d_2(n_2-1)}{d_2-1}+1\right)k_s\rceil$
Removing a member from subnet	$(d_2h_2-1)k_s$
Removing a subnet	$(d_1h_1-1)k_s$

Total Communication Cost

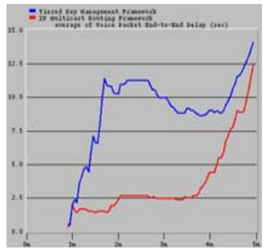
RP root	SKC	RP	Member
$\lceil\frac{(d_1n_1-1)}{d_1-1}k_s+n_1k_p\rceil$	$\lceil\frac{(d_2n_2-1)}{d_2-1}k_s+2\rceil$	$\lceil h_1+2\rceil$	$\lceil h_2+2\rceil$

Total Storage Cost

Simulation



Many-to-Many: Savings in Satellite Links



Many-to-Many: End-to-end Delay Comparison

Conclusion

• Proposed a hierarchical scheme that attempts to minimize control overhead in satellite links.
• Hides dynamism of join/leave in a subnet from other subnets.
• Attempts to mitigate the effect of root failure at the overlay level.
• Assumes minimal trust in the satellite infrastructure.
• "Fuses" key management at the application level (host) with management at the network level (RP).
• Essentially a generic design – different algorithms can be applied in each logical group depending on group dynamics.
• Future Work:
  • Fine-tuning of the mechanism for hiding the multicast data from the RPs.
  • Mechanisms for collusion resistance.
  • Source authentication of the multicast data.

Reference

1. A. Roy-Chowdhury. "IP Routing and Key Management for Secure Multicast in Satellite ATM Networks". Master's Thesis, University of Maryland College Park, 2003.

Acknowledgement

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