Proactive Key Distribution to support fast and secure roaming

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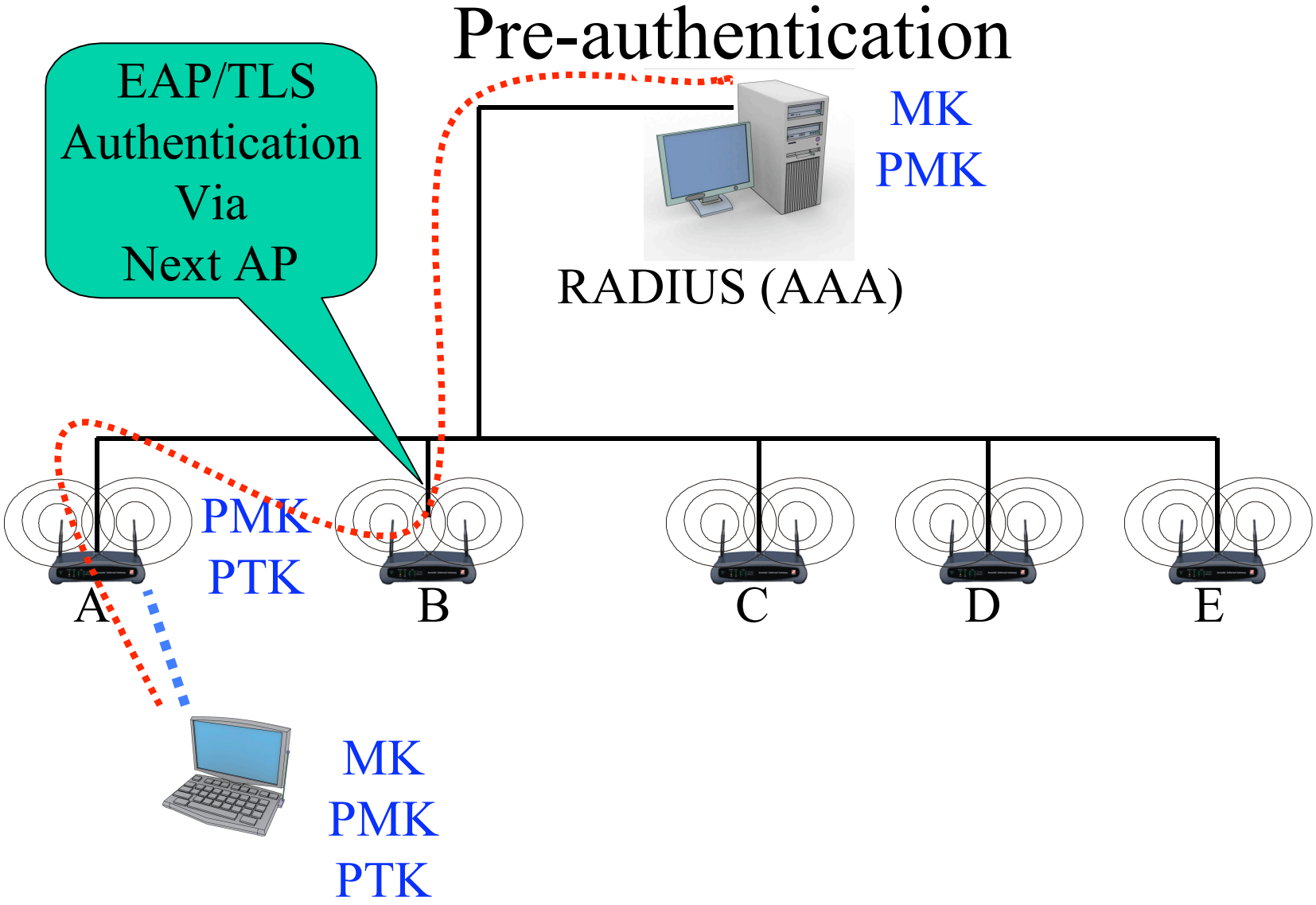
TGi MUST Support Fast Roaming

- Otherwise non-standard and non-vetted solutions will evolve….creating potential “brand” problems.
- Transparent roaming was one cause of exponential growth in the cellular market.
- Interworking is around the corner.

Backend Requirement

- Protocol MUST be standardized within IETF
  - This requires that key material NOT leave the AS.
  - This means that the protocol should fit within current and future AAA practice.

Pre-authentication



Problems with Pre-Auth

- Expensive in terms of computational power for client, and time (Full EAP-TLS can take seconds depending on load at RADIUS Server). TLS-Resume will make things faster, but other problems persist.
- Requires well designed and overlapping coverage areas
- Can not extend beyond LAN
- No opportunity for Interworking

Goals

- Permit fast roaming without reducing overall security
- Fast roaming occurs when the total cost of Layer 1-3 hand-off times is less than 50ms (Ideally 35ms).

TGi Fast Roaming Goals

- Handoff to next AP SHOULD NOT require a complete EAP/TLS re-authentication.
- Compromise of one AP MUST NOT compromise past or future key material, i.e. *perfect forward secrecy, and with stand known key attacks*.

TGi Trust Assumptions

- AAA Server is trusted
- AP to which STA is associated is trusted. All other AP's are untrusted.

Only Three Ways to meet TGi Goals

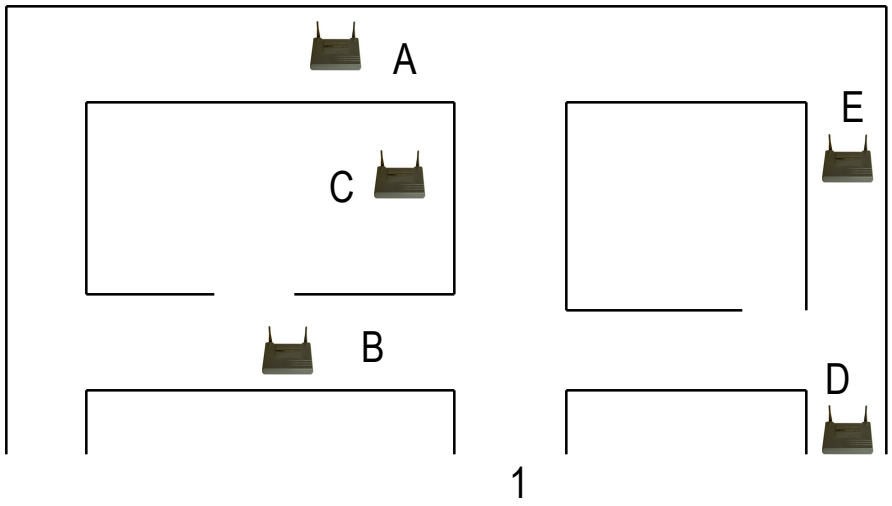
- Exponentiation support for asymmetric cryptographic operations at AP, or
- Trusted Third Party, i.e. Authentication/Roaming Server

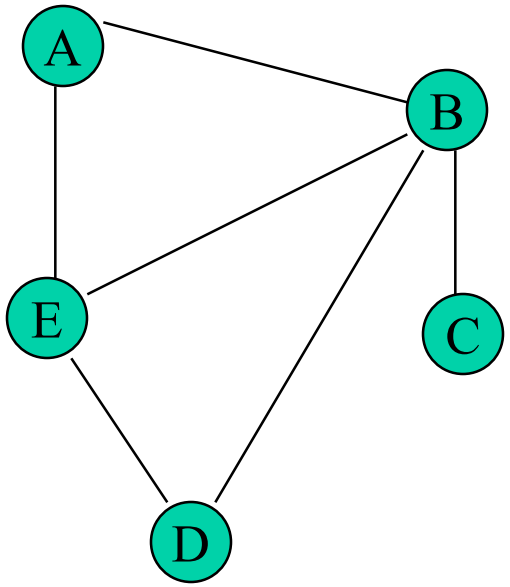
Proactive Key Distribution (TGi)

- Extend Neighbor Graphs and Proactive Caching (IEEE 11-02-758r1.ppt) to support key distribution by the AS
- Eliminates problems with sharing key material amongst multiple APs
  - Easily extended to support WAN roaming
  - Extendable to support Interworking

Neighbor Definition and Graph

- Two APs *i* and *j* are neighbors iff
  - There exists a path of motion between *i* and *j* such that it is possible for a mobile STA to perform a *reassociation*
  - Captures the '*potential next AP*' relationship
  - Distributed data-structure i.e. each AP or AS/RS can maintain a dynamic list of neighbors





AP Neighborhood Graph – Automated Learning

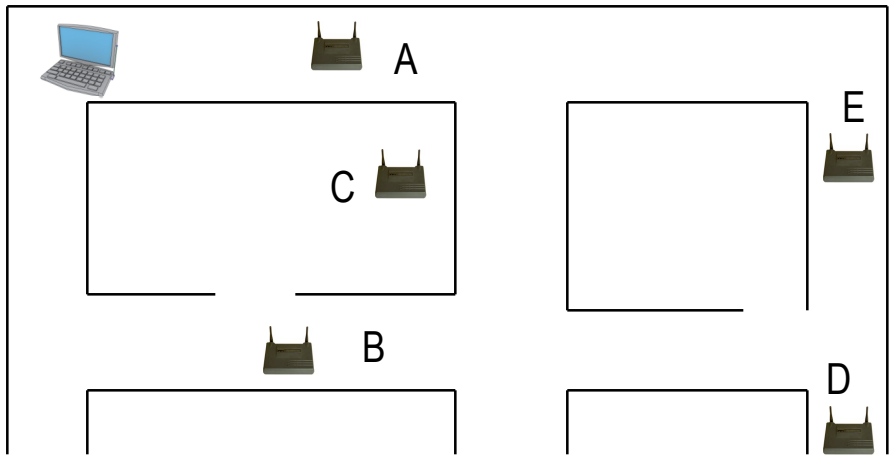
- Construction
  - Manual configuration for each AP/RS or,
  - AP/RS can learn:
    - If STA *c* sends *Reassociate Request* to AP *i*, with old-ap = AP *j* :
    - Create new neighbors *(i,j)* (i.e. an entry in AP *i*, for *j* and vice versa)
    - Learning costs only one '*high latency handoff*' per edge in the graph.
    - Enables mobility of APs, can be extended to wireless networks with an ad-hoc backbone infrastructure.
    - Dynamic implementation using LRU replacement permits invalid and stale entries to time out.

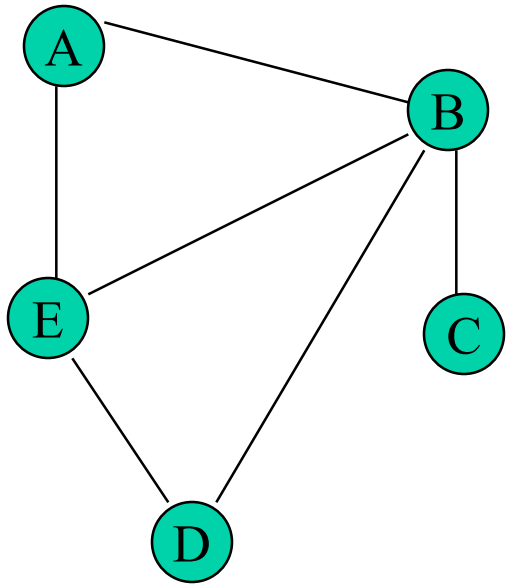
Graph Synchronization

- The graph's state at the accounting server is updated by:
  - Accounting-Request messages from the current AP (draft-congdon-radius-8021x)

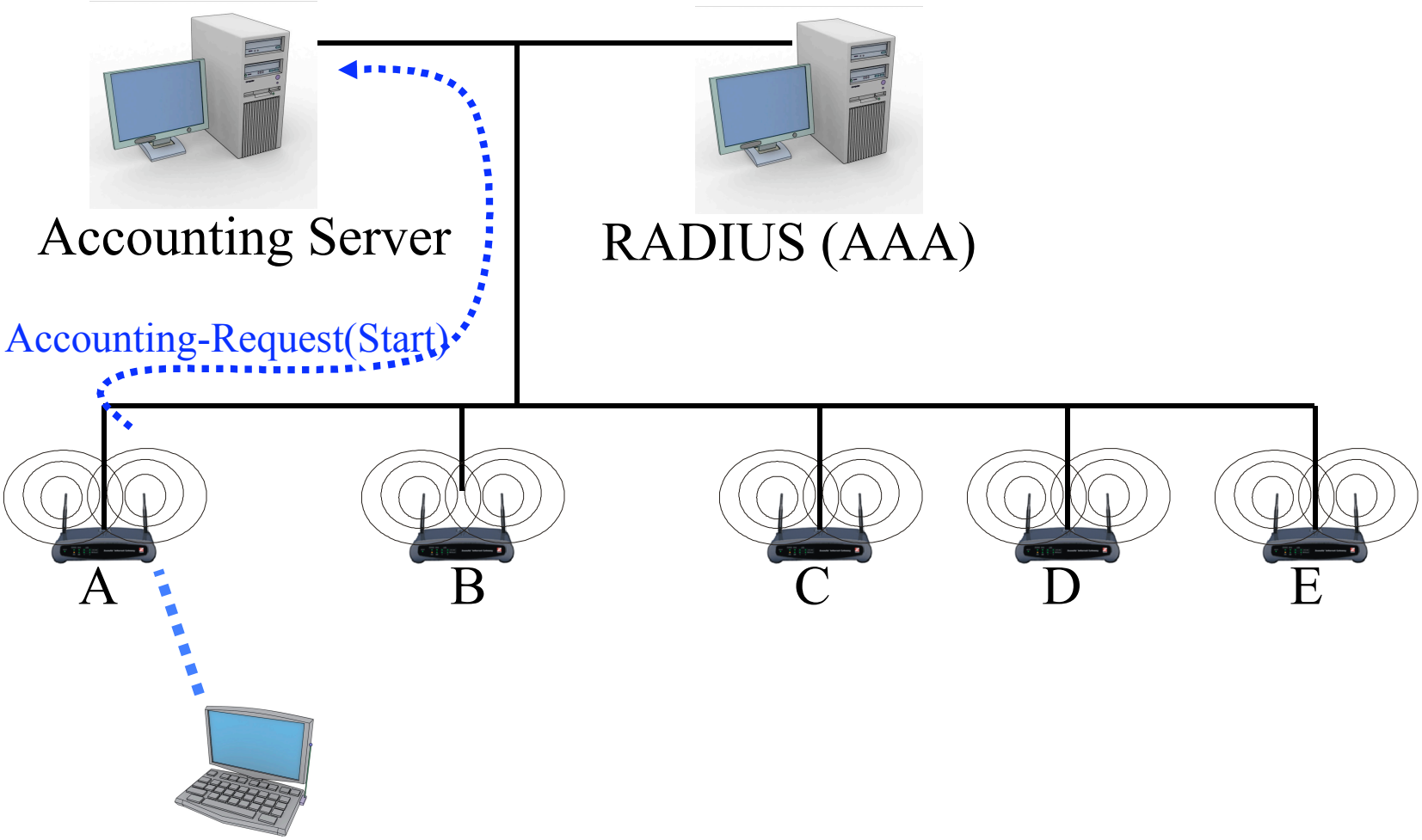
Roaming Example

- Given the following infrastructure with associated neighbor graph with STA about to associate to AP A.

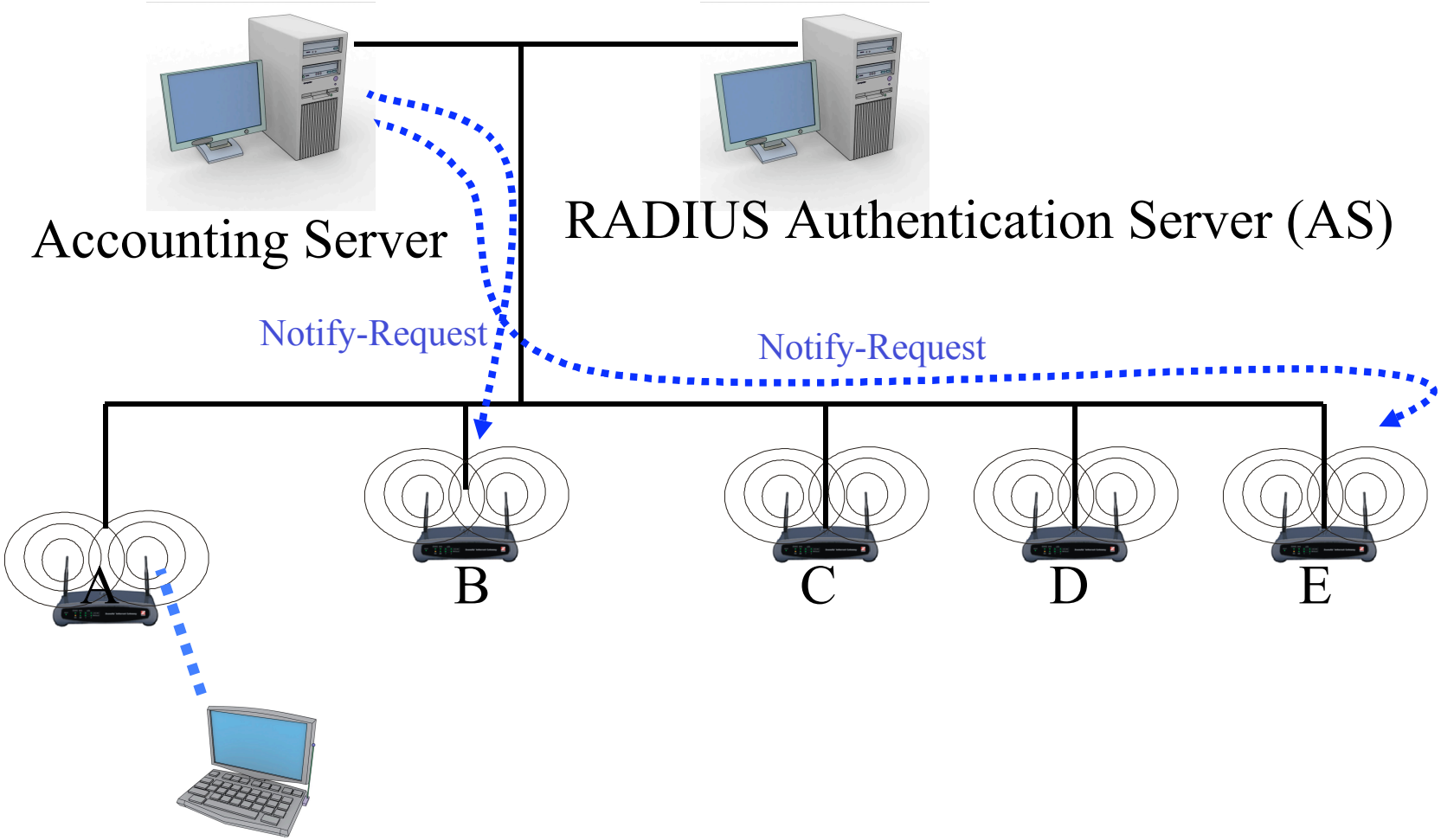




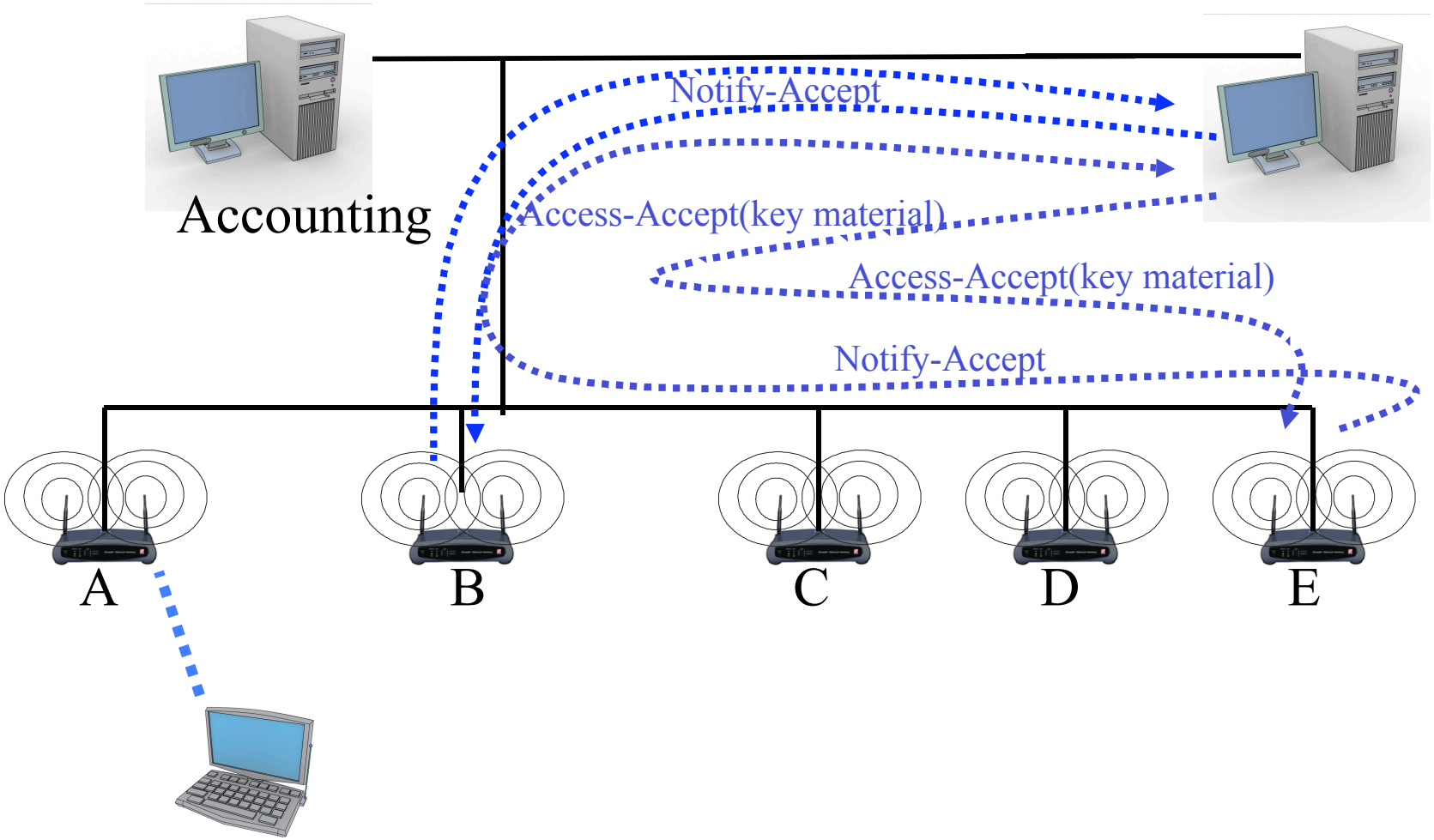
Post Authentication and 4-handshake



Proactive Key Distribution



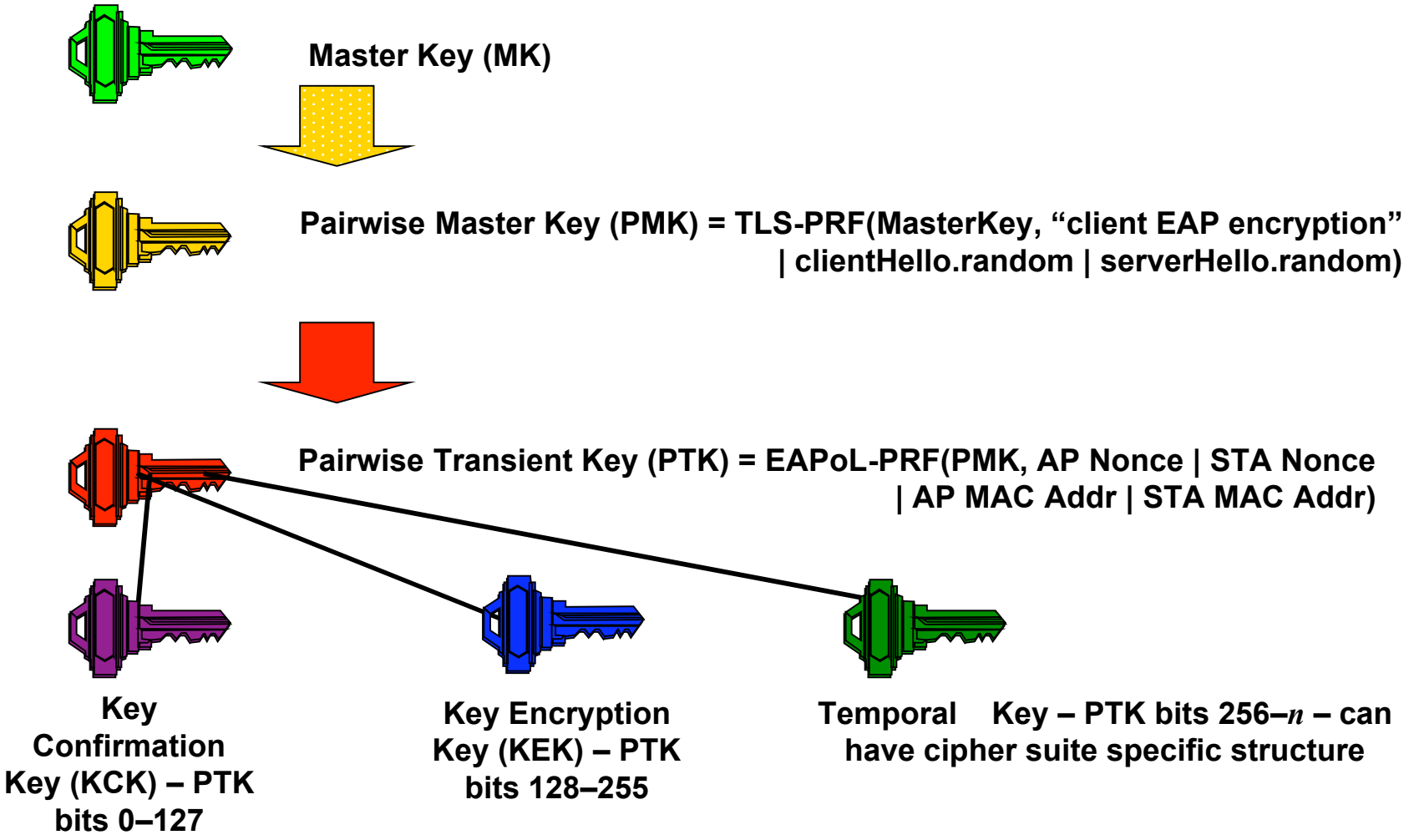
Proactive Key Distribution Post Authentication



AP Actions on Notify Request

- Dynamic Keys, i.e. PMK changes per roam.
  - AP MUST send an ACCESS-REQUEST to AS
- Static Key, i.e. PMK is unique per AP but never changes.
  - Nothing unless authorization is required.

TGi Pairwise Key Hierarchy Review



PMK Generation

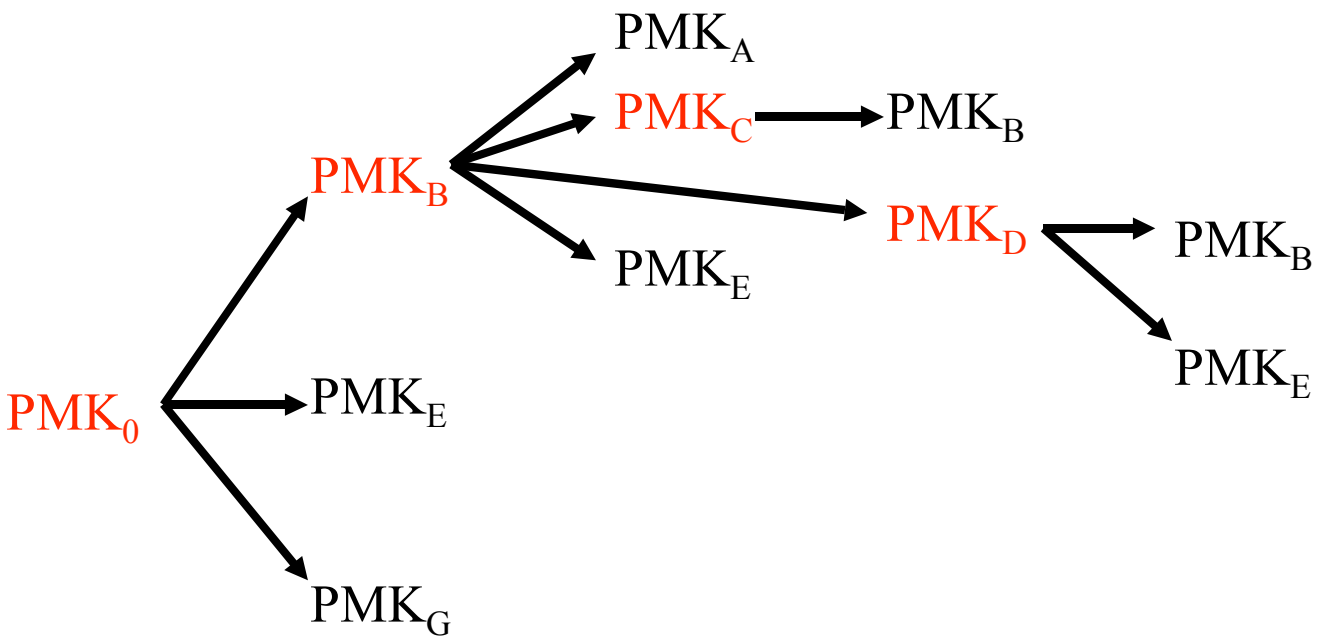
- Each AP is given a unique PMK per roam, or generation.
- The PMK for the AP for that generation becomes that generation's PMK.

PMK Generations

- Generation:
  - PMK_0 = TLS-PRF(MK,"client EAP encryption", client-Hello.random, serverHello.random)
  - $PMK_{1\text{-}B}$ = TLS-PRF(MK, PMK_0,AP_B-MAC-Addr)
  - $PMK_{1\text{-}E}$ = TLS-PRF(MK, PMK_0,AP_E-MAC-Addr)
  - $PMK_{2\text{-}C}$ = TLS-PRF(MK, $PMK_{1\text{-}B}$,AP_C-MAC-Addr)

Synchronization Example

STA roam pattern: A→B →C ≈ D



Synchronization

- One of two cases exist:
  - 1) AP and STA share correct generation of PMK, or
  - 2) They do not.
- STA ALWAYS has the correct PMK.
- The hand-shake determines which case exists and if the situation is case 2) then a full re-auth is completed. NOTE: The ~10ms it takes to determine the appropriate case is lost in the "noise" of a full EAP/TLS at ~800ms.
- Can be greatly improved by enforcing an invariant that a PMK for a STA only exists at current and neighboring AP's (requires new message to draft-irtf-aaaarch-handoff-03.txt).

How do the AP and STA know that Fast Roaming is supported?

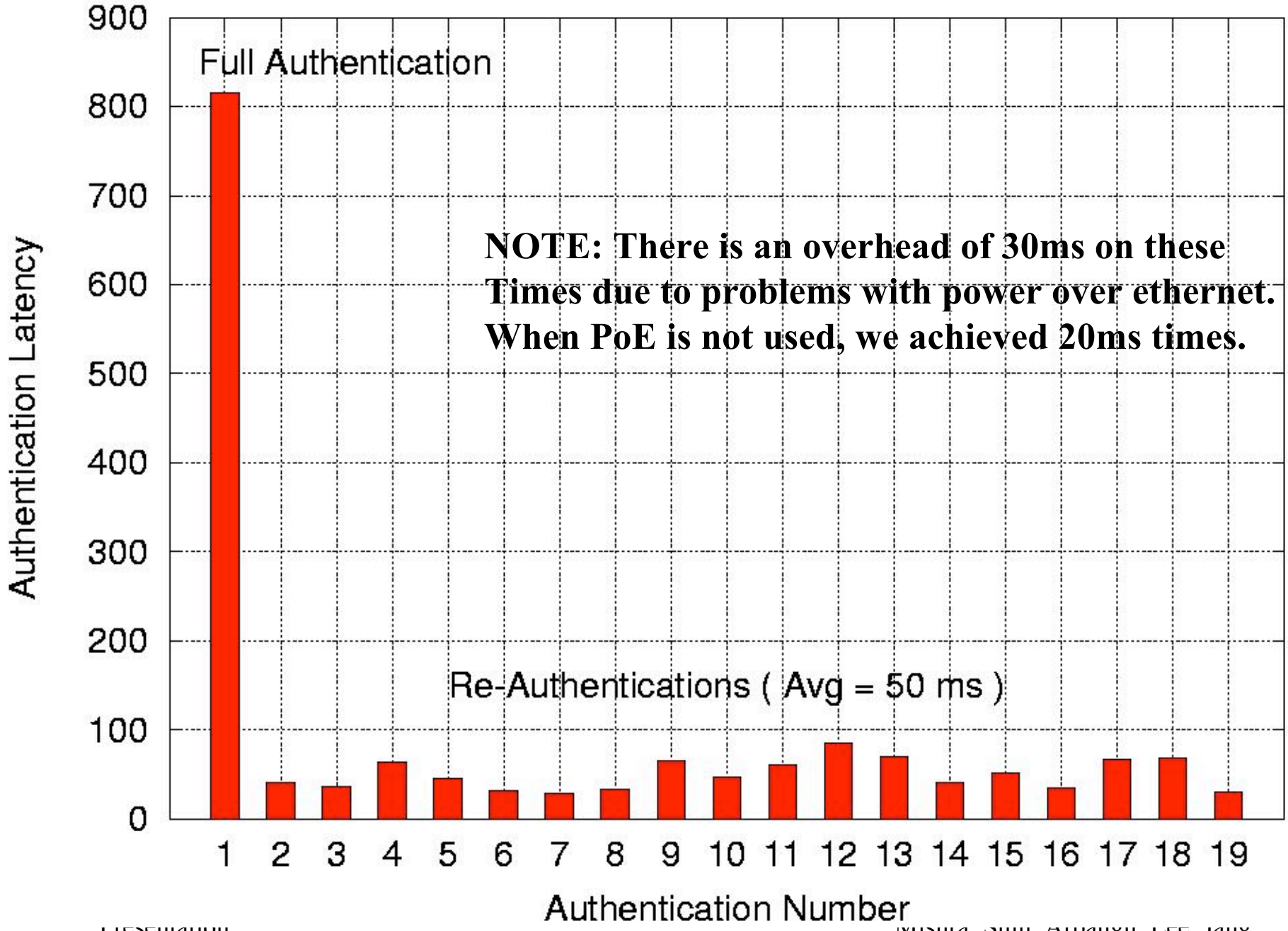
- STA asserts that it supports fast roaming by setting a bit (use of the current reserved bits) in the RSN information field element in the REASSOCIATION-REQUEST.
- AP asserts the same bit in the REASSOCIATION-RESPONSE *if and only if* the AP supports fast roaming and it is provisioned with a derived PMK for the STA.
- If either bits are unset, then a full reauthentication MUST be done.

Implementation Results

- Significantly easier to implement than expected.
- Little traffic increase on distribution system.
- Synchronization MUCH easier than expected.
- Reduced hand-off times from a full EAP/TLS by a factor of 40!
- Full paper available at:

  http://www.cs.umd.edu/~waa/pro-key.pdf

  – Please do not re-distribute paper


Full Authentication
NOTE: There is an overhead of 30ms on these Times due to problems with power over ethernet. When PoE is not used, we achieved 20ms times.
Re-Authentications (Avg = 50 ms)
Authentication Latency
Authentication Number
0
100
200
300
400
500
600
700
800
900
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Advantages

- Permits fast roaming with little to no changes within current draft.
- Provides similar level of security as a full re-authentication
  - New PMK
  - Interaction with AAA server to authorize access
- Actually has been implemented!

Disadvantages

- Does require server changes, but pre-auth can be used until server changes occur (besides server changes are minor).

What needs to be done?

- Adjust to EAP key hierarchy.
- Use PMK name (once defined) rather than generation.
- Add invariant message.
- Add fast-roam bit to IE.

Maximum STA Velocity

For the Notify and PMK install to occur in time, we need:

2 RTT + handshake < D/v

Where:

D = coverage diameter

v = STA velocity

RTT = round-trip time from AP to AAA server, including processing.

Assuming D=100 ft, handshake = 10 ms, and RTT = 100ms, we get:

v = 100 ft/ (200ms + 10 ms) ~ 500 ft/sec = **Mach 0.5!!**

Conclusions

- Provided an overview of various options
- Provided a protocol that:
  - Can support high speed roaming, meets IETF requirements (draft-arbaugh-radius-handoff-00.txt),
  - Is independent of the type of key management/derivation used (static or dynamic), i.e. can IEEE11-03-008r0-I or the method in the information slides of this presentation.
  - Is independent of the type of hand-shake used.

Acknowledgements

- Bernard Aboba assisted with the best way to integrate Proactive key distribution with RADIUS.
- The maximum STA velocity calculation is from Bernard Aboba.
- Jesse Walker pointed out potential synchronization problems in an earlier version of proactive key distribution.