The Convergence of Ubiquity: The Future of Wireless Security

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Talk Overview

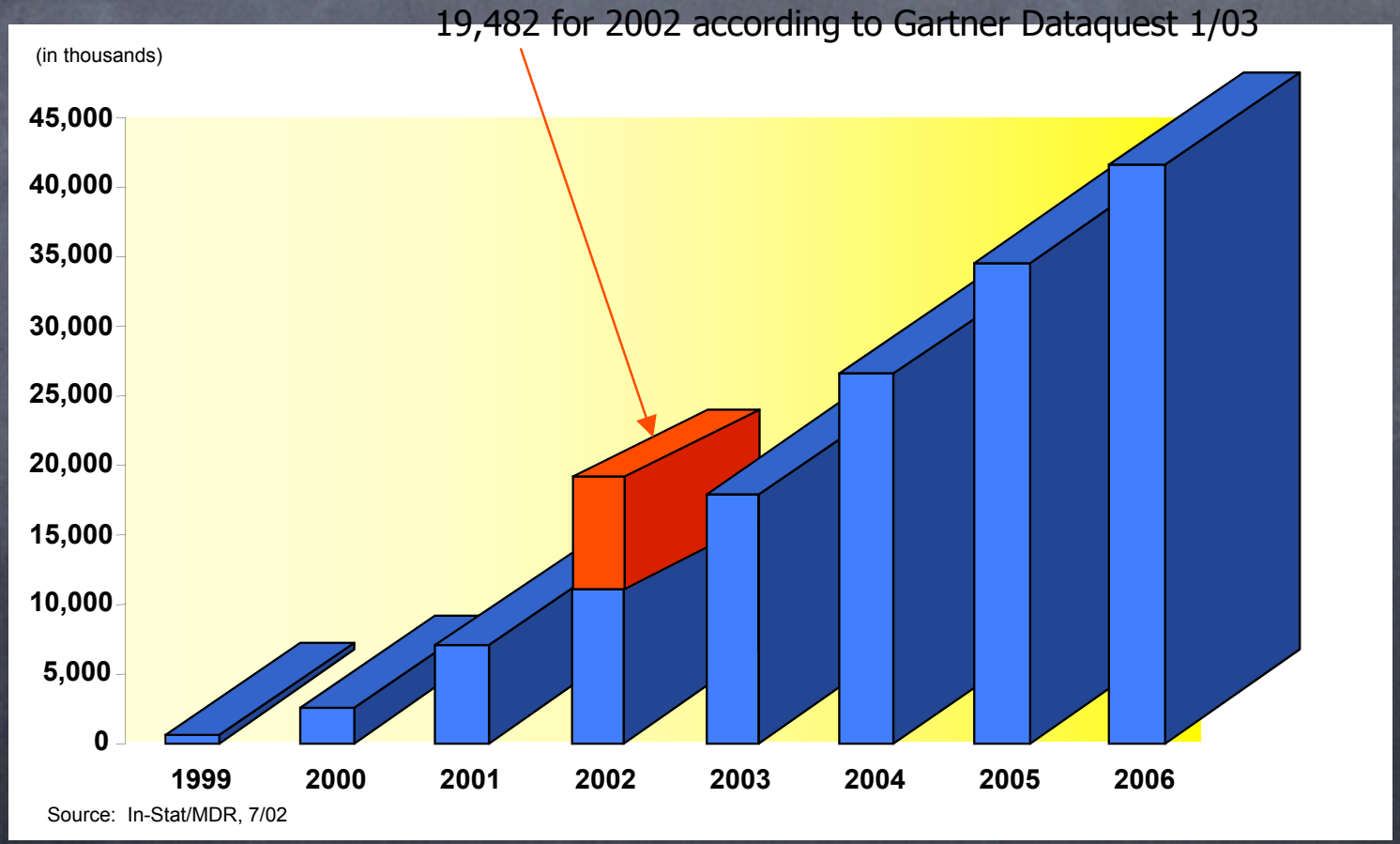
(with apologies to Dickens)

- Wireless Networking Overview
  - Why Wireless Security is Different
  - Hop by Hop vs. End to End
- The Ghosts of Wireless Security Past

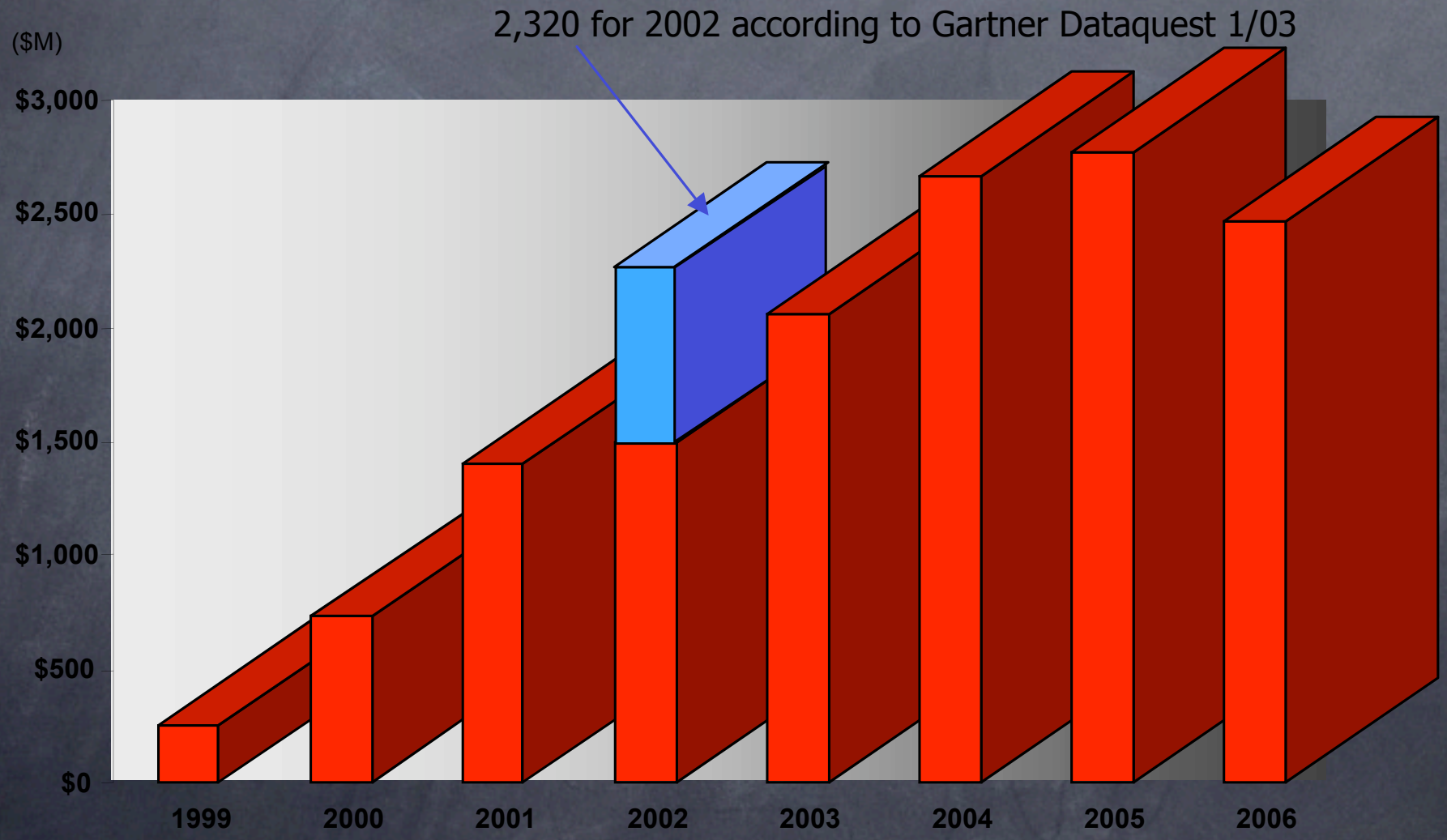
- The Ghosts of Wireless Security Present
  - Wi-Fi Protected Access
  - Denial of Service
- The Ghosts of Wireless Security Future
  - Trends
  - Interworking
  - Device security

Wireless Networking is Experiencing Exponential Growth

WLAN Shipments



WLAN Sales



Source: In-Stat/MDR, 7/02

Wireless Networking

- The next Internet, or

or the next Bubble?

The Future of WLAN's?

- 4G?
- Hot spot coverage only ala Boingo et. al?
- Or some sort of overlay blend?
- Regardless- the rapid growth will continue.

WLAN Urban Legend

- 802.11b is "secure" because it uses frequency hopping or spread spectrum!
- Using IPsec or SSH is all that's needed to provide complete security!
- I haven't heard of anyone's WLAN being exploited- so I'm OK!
- All of the known attacks require a sniffer which is difficult to find and expensive. Thus, you're safe!
- Attacking WLANs requires expensive and specialized tools!

The Threat

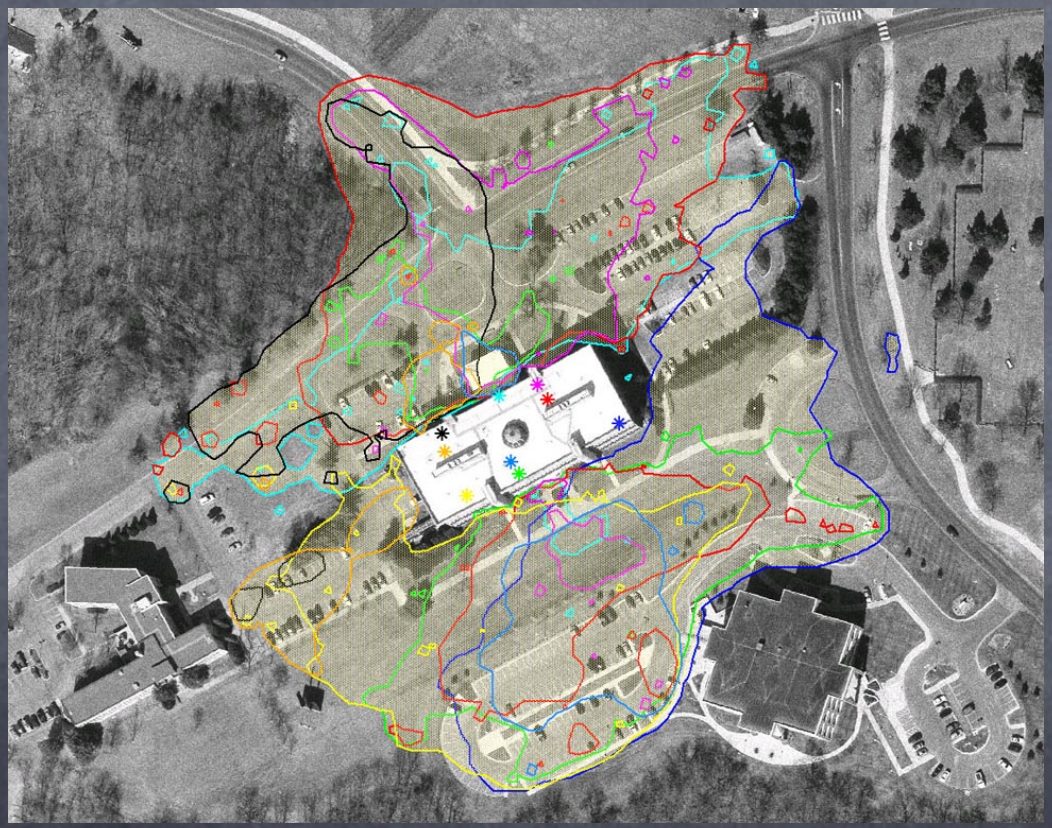
- In general, there are four threat classes[1]:
  - Journeymen (Class 0)
  - Experts (Class 1)
  - Insiders (Class 2)
  - Well funded professionals (Class 3)

1. Modifications to the model originally proposed by [Abraham et. al.].

Why Wireless Security is Different

- An attacker has access to the transport medium of your network!
  - Essentially elevates the experts to an insider (higher threat)

The Wireless Threat



Used with permission from KARS: http://www.ittc.ku.edu/wlan/

Hop by Hop vs. End to End

- End to end security is necessary, but only sufficient if and only if strong mutual authentication occurs.
  - PEAP attack [Asokan, et.al.]
  - Human factors, e.g. "Social Engineering"
  - Requires global non-forgeable identity

- End to End can not guarantee availability!
  - Routing attacks
  - Michael DoS (We'll see this later)

Wired Equivalent Privacy

- What exactly does that mean?
- My guess:
  - Prevent unauthorized use (access control, authentication, and integrity)
  - Prevent unauthorized disclosure (confidentiality)
  - ~~Prevent unauthorized eavesdrop~~ping (Not likely to happen in consumer wireless)

Identity

- The current standard only uses the MAC address as a form of identity.
  - Unfortunately, the MAC address is malleable and further compounded by inadequate cryptographic binding [Walker, Borisov et. al., Arbaugh et. al.].
- The future standard uses two forms of identity: MAC address at the link layer, and a user ID at the network layer.
  - Requires cryptographic binding between the two ID's [Mishra et. al.].
  -

- *nb*. History buffs will remember that the AMPS (Cellular) system made the same mistake with the equipment serial number (ESN).

Access Control

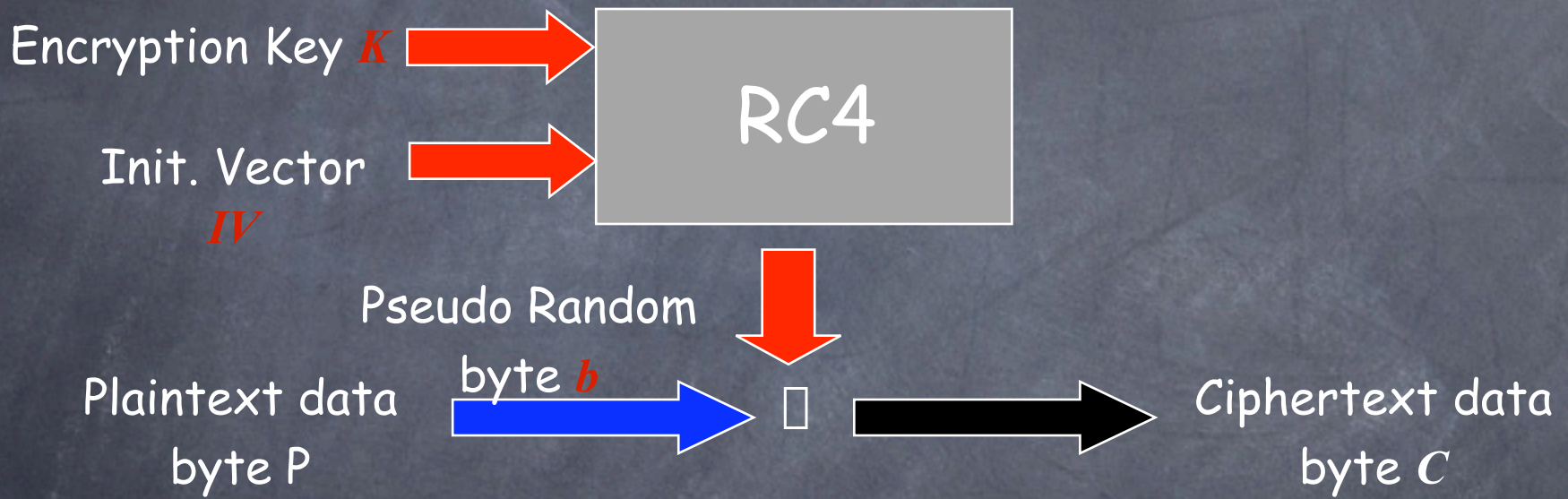
- MAC access control lists
  - MAC address is forgeable [Arbaugh et. al.]
- Proprietary "closed network" used a shared secret as access token.
  - Access tokens broadcast in the clear in management frames [Arbaugh et. al.]
  -

nb. Here the reliance on the expense/difficulty in eavesdropping as a security mechanism is again a mistake the cellular community made.

Integrity

- The lack of any message authenticity mechanism, or the reliance on error detection (CRC) for integrity protection.
  - A linear CRC combined with a linear combiner, XOR, allows "bit flipping" [Borisov et. al.].

WEP Block Diagram



Decryption works the same way: $P = C \oplus b$

Confidentiality

- IV space is only 2^{24}
  - Creates Depth [Walker, Borisov et. al.]
    - $c_1 \oplus c_2 = (p_1 \oplus r) \oplus (p_2 \oplus r) = p_1 \oplus p_2$
- Lack of Replay protection combined with stream cipher
  - Asynchronous known plaintext attack [Walker, Borisov et. al.]
  - Synchronous known plaintext attack [Arbaugh]
- IV as first part of key
  - Induces several classes of weak IV's. The most damaging being when the IV is of the form <n,FF,x> [Fluhrer et. al.]

Mitigating FMS

- Most all vendors have implemented IV filtering to prevent FMS attacks.
- Reduces IV space from 2^{24} to 2^{18} in some cases.
- Prevents FMS attack that required on average several hours, but ....
- Reduces the work-factor of a previous attack (Inductive Chosen Plaintext) from 18 hours to 80 minutes!!!

Authentication

- The use of a challenge response system covered by a Vernam cipher.
  - Eavesdropping on a single successful authentication provides the attacker the ability to authenticate at will [Arbaugh et. al., Borisov et. al., Walker]

The Ghosts of Wireless Security Present

Wi-Fi Protected Access (WPA)

- Announced early of this year by WECA
- Available real soon now
- Essentially a subset of IEEE draft
- Designed to support legacy equipment via new firmware and drivers

WPA

- Confidentiality: Per-packet keying via TKIP
- Message Authenticity: Michael algorithm via TKIP
- Access Control: IEEE 802.1x
- Authentication: EAP/TLS

WPA Commentary

- WPA will provide a tremendous increase in security
- However, WPA is based on several new and domain specific protocols
- As such- it SHOULD only be considered as an interim solution until Robust Security Network, aka WPA2, equipment becomes available

RSN aka WPA2

- Due "Real Soon Now" - actually product won't ship until Q3 or Q4 2004.
- Will require hardware upgrades to support AES in most cases (some of the newer cards/AP's may not).

- Confidentiality: Per-packet keying via TKIP or AES CCMP
- Message Authenticity: Michael algorithm via TKIP or AES CCMP
- Access Control: IEEE 802.1x
- Authentication: EAP/TLS

Both WPA and RSN

- will provide tremendous improvements in Confidentiality, Integrity, Authentication, and Access Control
  - but ……
- Availability will remain an issue

Denial of Service

- ALL past, current, and future Wi-Fi standards are susceptible to Denial of Service attacks at multiple layers.
  - Layer 3 (EAP DoS)
  - Layer 2 (Michael DoS, unauthenticated management frames)
  - Layer 1 (CTS, Power Save)

The Ghosts of Wireless Security Future

Trends

- Computing devices shrinking and becoming more capable
- Networks becoming ubiquitous
- Users becoming more mobile
- Content becoming active
- Software defined radios appearing

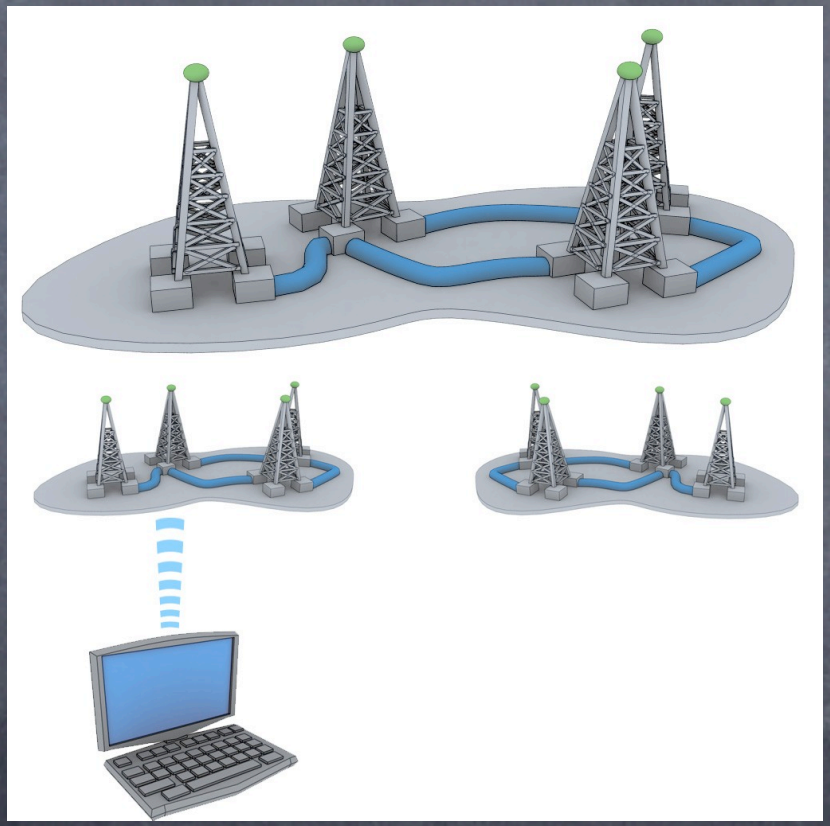
What is Interworking

- Interworking permits the user to transparently roam between different networks- usually with different PHY and administrative domains.

Transparent Roaming / Interworking

CDMA

WLAN

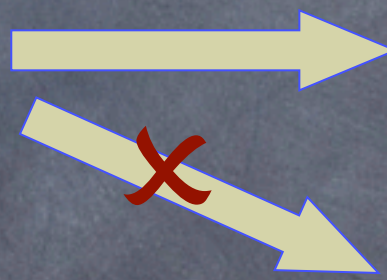


Why is Interworking Important?

- Ubiquity : User's are demanding continuous connectivity.
  - Ease of use requirements demand transparency.
  - Sound business practice (and user privacy requirements) demand security.

Interworking Properties

- Security
  - Transparency
  - Simplicity



Availability
User's :-)
$$$

Denial of Service
Fraud
User Complaints

Wireless Device Security and Firewalls

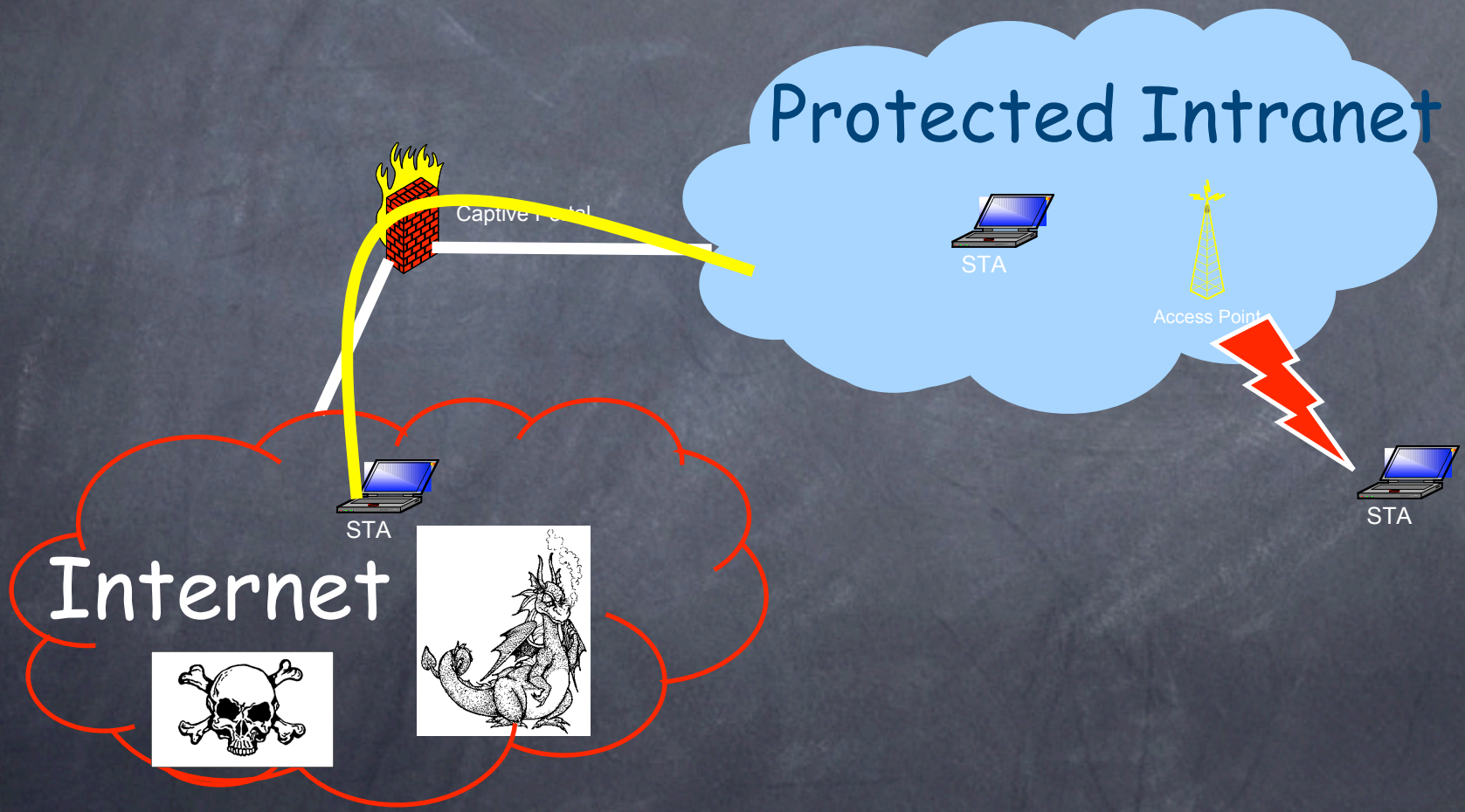
- In the future everything will radiate- your fridge, your picture frame, even down to small parts (RFID).
- Most of these devices will also have IP addresses- Imagine the headline:

Amazon DoS'd by Fridges,
Toasters and phones - oh my!

Current Environment

- Small and large companies using Firewalls and anti-virus as the ONLY means of protection.
- Many home users connect via cable or DSL with no protection.
- Users are moderately mobile (Discrete Operation)
  - Laptops while traveling
  - VPN used to connect to office
- This simple operating model has created a significant management problem

Some of the Problems with Firewalls



Today's Firewall

- Not as effective as a decade ago because of multiple "piercings"
  - User mobility creates potential vector for malice
  - Active content
  - User "creativity"
  - Crappy software
  - Peer to Peer programs

Future Environment

- Dramatic increase in mobility (always on)
  - Ubiquity of network access
  - Ubiquity of more powerful computing devices
  - IPv6, i.e. every device has a routable IP address
  - Active content increasing
  - Peer to Peer increasing

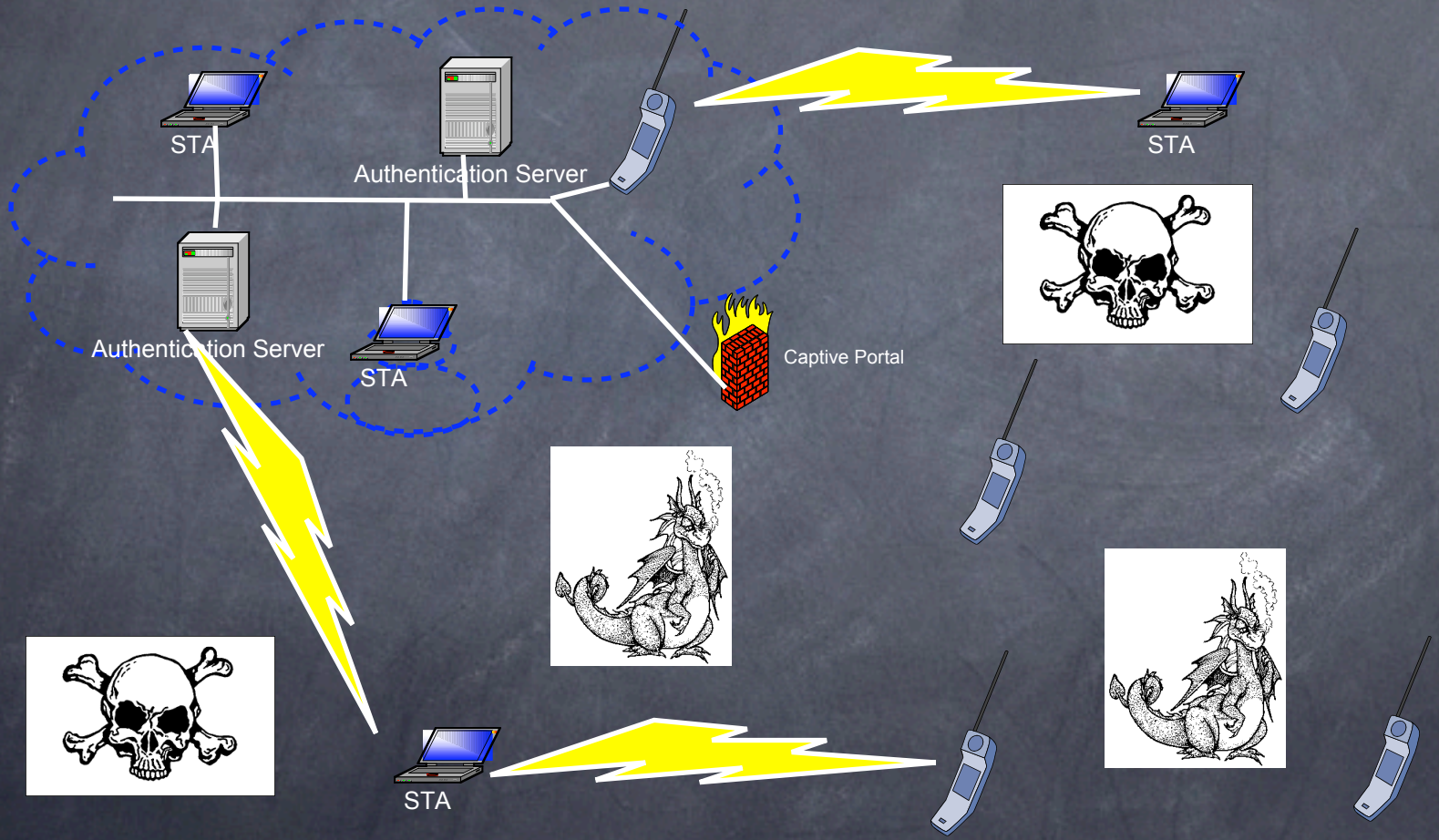
Future Environment

- Devices may require multiple management sources
  - A handset may need to receive updates from the manufacturer,
  - The developers of installed applications, and
  - Receive user and/or organizational data

Future Environment

- Management will become significantly more difficult
  - Separation of management instructions is a MUST,
  - Many organizations will want to be "in the loop" on all management instructions,
  - Devices are "always on"

The Future


STA
Authentication Server
STA
Authentication Server
STA
Captive Portal
STA

Conclusions

- Things are bad, but they are getting better. However, numerous challenges exist before we can have complete and secure ubiquitous computing.