

Residential Broadband (RBB)

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Service Aspects and Applications (SAA)

- q Voice and Telephony over ATM (VTOA)
- q Residential broadband services (RBB)
- q Audiovisual multimedia services (AMS) Phase 1: Video on demand
- q AMS Phase 2: Video conferencing
- q ATM Name Service (ANS)
- q Native ATM Services (API)



- q Technologies for high-speed access to home
- q ATM over these technologies
- q IEEE 802.14 standard

Residential Broadband (RBB)

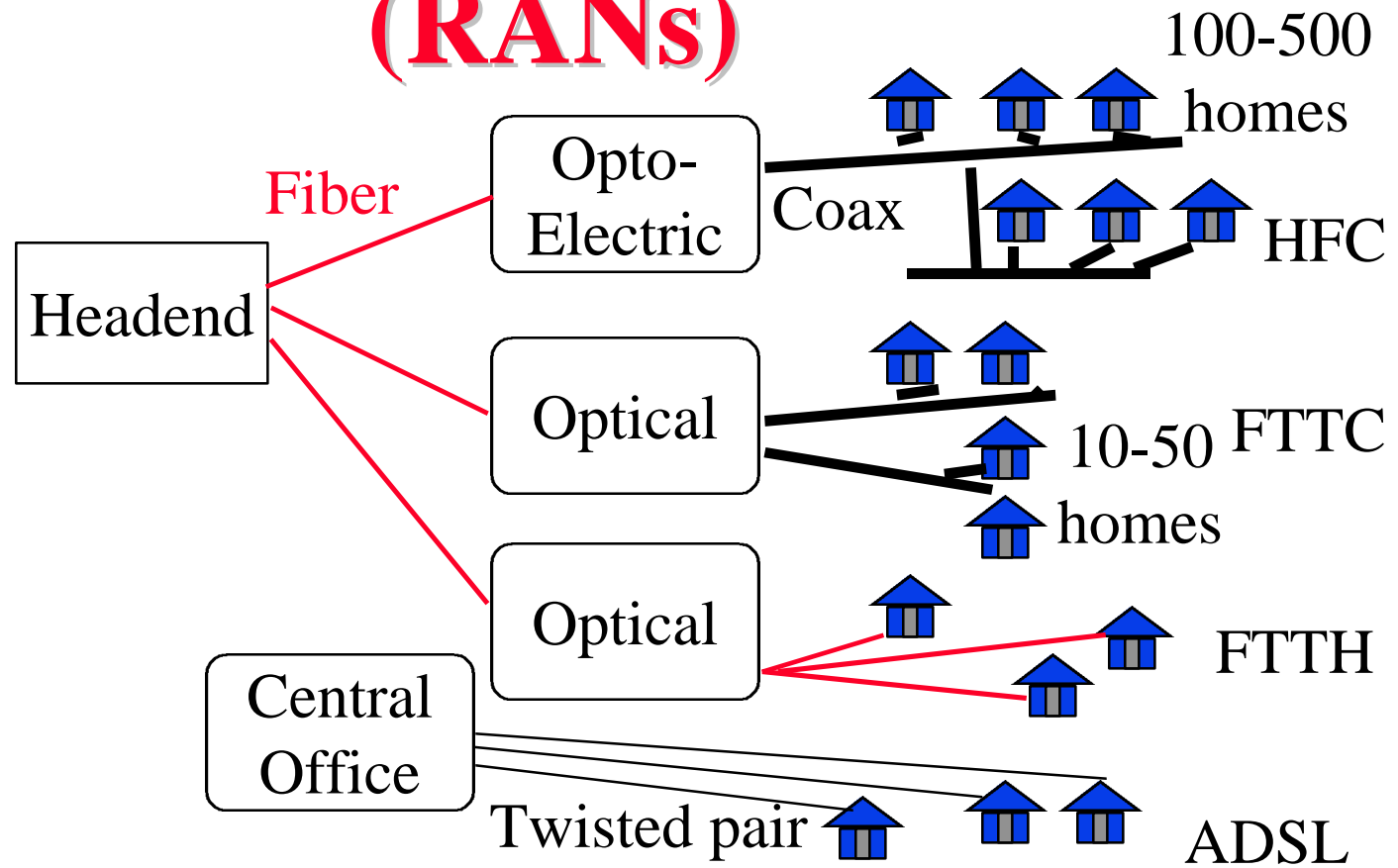
- q Also, Residential and Small Business Broadband (RSB) in the marketing arm of ATM Forum
- q High-speed access to homes
- q RJ-11 like universal interface to devices
- q Existing cable TV has the media but no switching
- q Existing phone service has switching but not enough bandwidth

Potential Applications

- q Video on demand (VOD)
- q Near video on demand (NVOD) - staggered starts
- q Distance learning
- q Home shopping
- q Telecommuting
- q Teleconferencing
- q Meter reading
- q Security
- q Telemedicine

Residential Access Networks

(RANs)



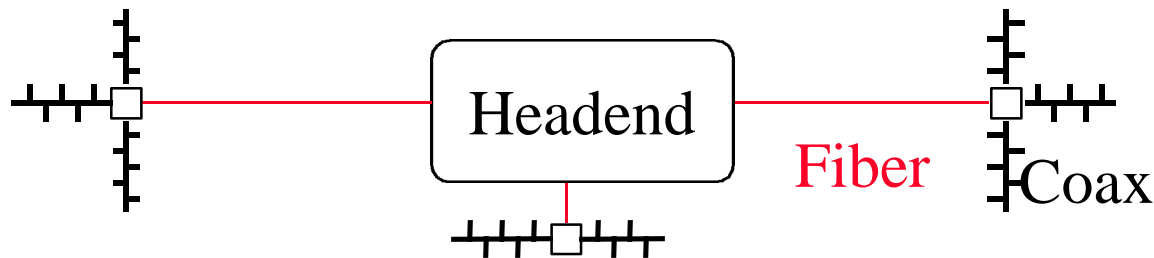
ADSL

- q Asymmetric Digital Subscriber Line
- q Asymmetric \Rightarrow upstream \ll Downstream
- q Modem technology
- q 6 Mbps downstream, 640 kbps upstream
- q Using existing twisted pair lines
- q No interference with phone service (0-3 kHz)
 \Rightarrow Your phone isn't busy while netsurfing
- q Up to 7500 m
- q Being standardized by ADSL forum
- q Quickest alternative for Telcos

Very High Speed DSL (VDSL)

- q Up to 50 Mbps downstream, 5 Mbps upstream
- q Up to 1500 m
- q Larger bandwidth for shorter distances and vice versa
- q 51.84 Mbps at 300 m, 25.92 at 1000 m, 12.96 at 1500 m
- q Reuse existing telephone twisted pair wiring
- q Point-to-point topology \Rightarrow Bandwidth not shared
- q Co-exist with POTS or ISDN on the same pair
- q Twisted pair \Rightarrow EMI \Rightarrow withstand legal 400W radio transmissions at 10 m

Hybrid Fiber Coax (HFC)



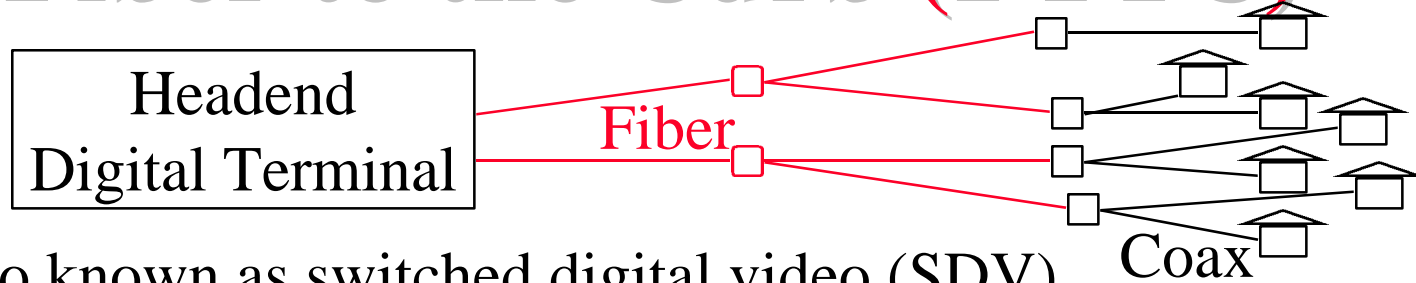
- q Reuse existing cable TV coax
- q Replace trunks to neighborhoods by fibers
- q 500 to 1200 homes per HFC link
- q 45 Mbps downstream, 1.5 Mbps upstream
- q MAC protocol required to share upstream bandwidth
- q Several homes share the cable TV
- q Sharing \Rightarrow Security issues
- q IEEE 802.14 is standardizing MAC and PHY

HFC Spectrum



- q Use 0-50 MHz for upstream, 50-450 MHz for analog broadcasts, 450-750 MHz for downstream
- q Can use phone, TV, and Internet simultaneously
- q Low upstream band \Rightarrow more noise
- q Broadband \Rightarrow frequency multiplexing \Rightarrow Each home tunes to its channel
- q Quadrature amplitude modulation (QAM-64) can give 27 Mbps over 6 MHz channel

Fiber to the Curb (FTTC)



- q Also known as switched digital video (SDV)
- q Coax and twisted pair for the last 100-300 m
- q Coax is used for analog video, TP is used for POTS
- q Baseband \Rightarrow No frequency multiplexing
- q Passive optical network \Rightarrow signal is optically broadcast to several curbs \Rightarrow Time division multiplexing
- q Up to 50 Mbps downstream, Up to 20 Mbps upstream
- q Co-exist with POTS or ISDN on the same cable pair
- q Twisted pair \Rightarrow EMI \Rightarrow withstand legal 400W radio transmissions at 10 m

FTTC MAC

- q Downstream uses periodic frames
- q Upstream should consist of fixed size slots containing one ATM cell
- q One upstream slot per n downstream frames
- q Some slots are reserved, others are for contention
- q Contention slots are used by devices undergoing activation

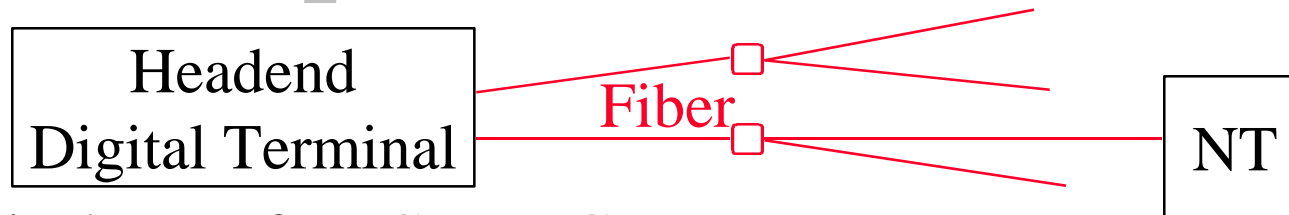
Cable Modems

- q Modulate RF frequencies into cable
- q Signal received at the headend and converted to optical
- q Cost \$395 to \$995
- q Internet access at 500 kbps to 4 Mbps
- q If cable is still one-way, upstream path is through POTS
- q \$30 to \$40 per month flat service charge
- q Successful trials in Canada using 500 kbps modems
- q After the trial 75% users decided keep the service and pay
- q TCI formed @Home <http://www.home.net>
- q Servers at headend to avoid Internet bottleneck
- q Plans to create high-speed cable backbone across the US

Fiber to the Home (FTTH)

- q Fully optical \Rightarrow No EMI
- q Initially passive optical network
 \Rightarrow Time division multiplexing
- q Upstream shared using a MAC
- q 155 Mbps bi-directional
- q Need new fiber installation

Passive Optical Networks (PONs)

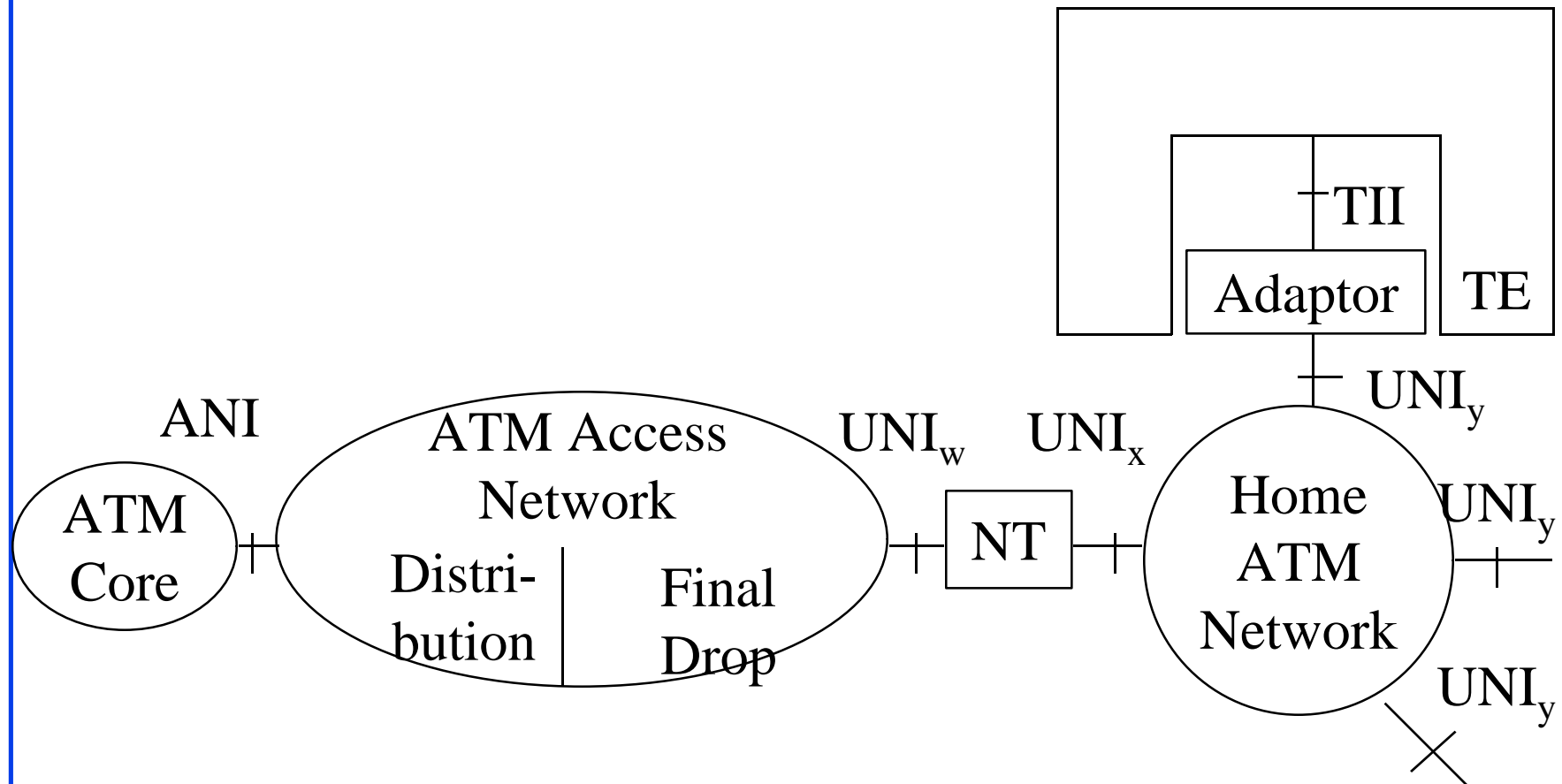


- q Optical part of HFC, FTTC, FTTH
- q Up to 10 km
- q 150 Mbps or more downstream
- q 50 Mbps or more upstream
- q Downstream signal is broadcast to all NTs
- q Downstream traffic has a destination address
- q Upstream transmission is controlled by optical line terminal (OLT)
- q Upstream bandwidth shared using a MAC
- q Timing reference transmitted downstream

Comparison of RANs

Technology	Typical Downstream Rate	Typical Upstream Rate	Maximum Distance	Homes Per Optical Unit
HFC	45 Mbps Shared	1.5 Mbps Shared	N/A	500
FTTC	25-50 Mbps	25-50 Mbps	100 m	10-50
FTTH	155 Mbps	155 Mbps	N/A	10-200
ADSL	6 Mbps	640 kbps	4000 m	1,000
VDSL	13-50 Mbps	1.6-5 Mbps	2,000 m	100

RBB Reference Configuration

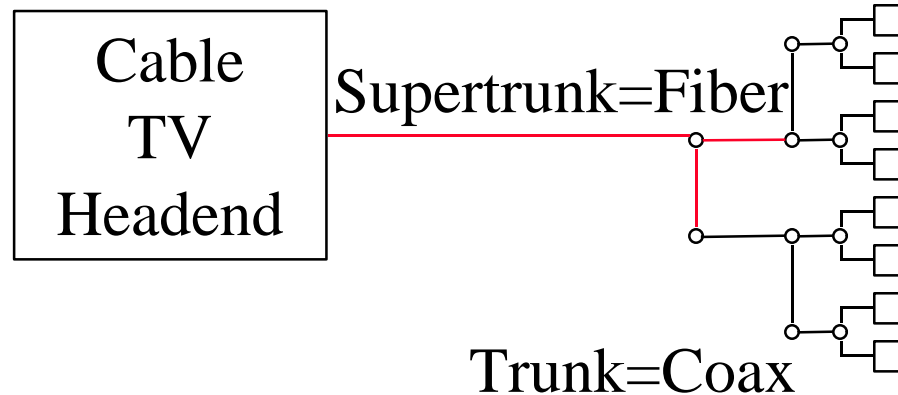


RBB Charter

- q To define:
 - q Home UNI (HUNI)
 - q UNI_x (where $x = \text{HFC, FTTC, FTTH, ADSL, ...}$)
- q Support end-to-end ATM
- q Point-to-point and point-to-multipoint VCs
- q All TM4.0 services: CBR, VBR, ABR, UBR

IEEE 802.14

- q CATV MAC and PHY Protocol working group
- q Started November 1994
- q Defining PHY and MAC for 2-way HFC
- q 17 MAC protocol proposals have been submitted
- q Downstream PHY: 1-to-n broadcast
- q Upstream PHY: n-to-1
- q Up to 50 miles (80 km) \Rightarrow 400 microsecond one-way



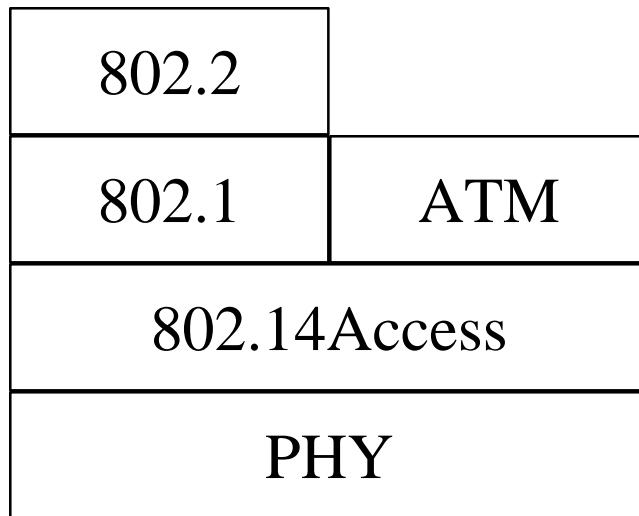
IEEE 802.14 MAC Requirements

- q Support both connectionless and connection-oriented services
- q Support QoS
- q Support CBR, VBR, ABR
- q Support Unicast, multicast, broadcast services

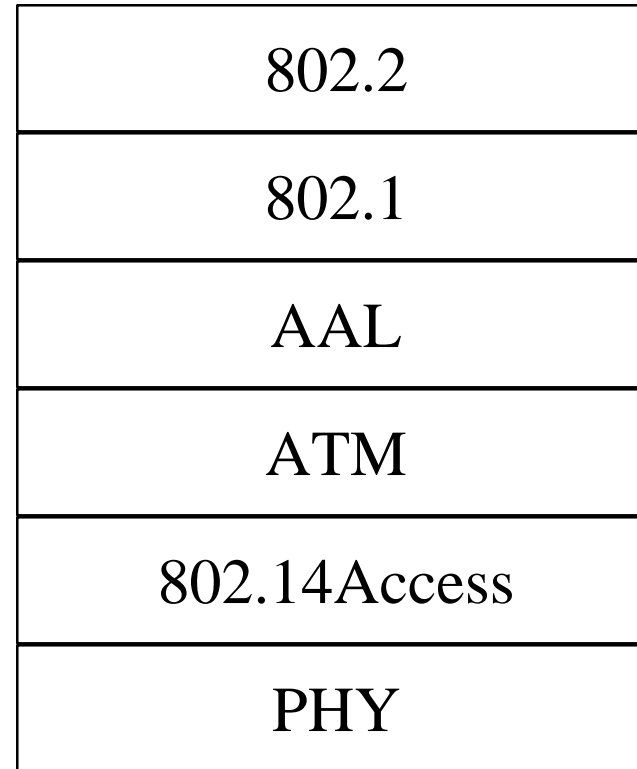
IEEE 802.14 PHY

- q 500 homes as a reference design point
- q Support sub-split (5-40 MHz upstream), mid-split (5-120 MHz upstream), and high-split (800-1000 MHz upstream)
- q Frequency reuse in upstream
- q Decided to use Quadrature Amplitude Modulation (QAM) 64 for downstream.
- q QAM-64 gives 6 bits/Hz \Rightarrow 30 Mbps on 6 MHz \Rightarrow 27 Mbps after FEC
- q Quadrature Phase Shift Keying (QPSK) may be selected for upstream to sustain high noise \Rightarrow 1.5 to 3 Mbps on 2 MHz
- q Several upstream channels per downstream channel

IEEE 802.14 Protocol Stack



ATM Friendly

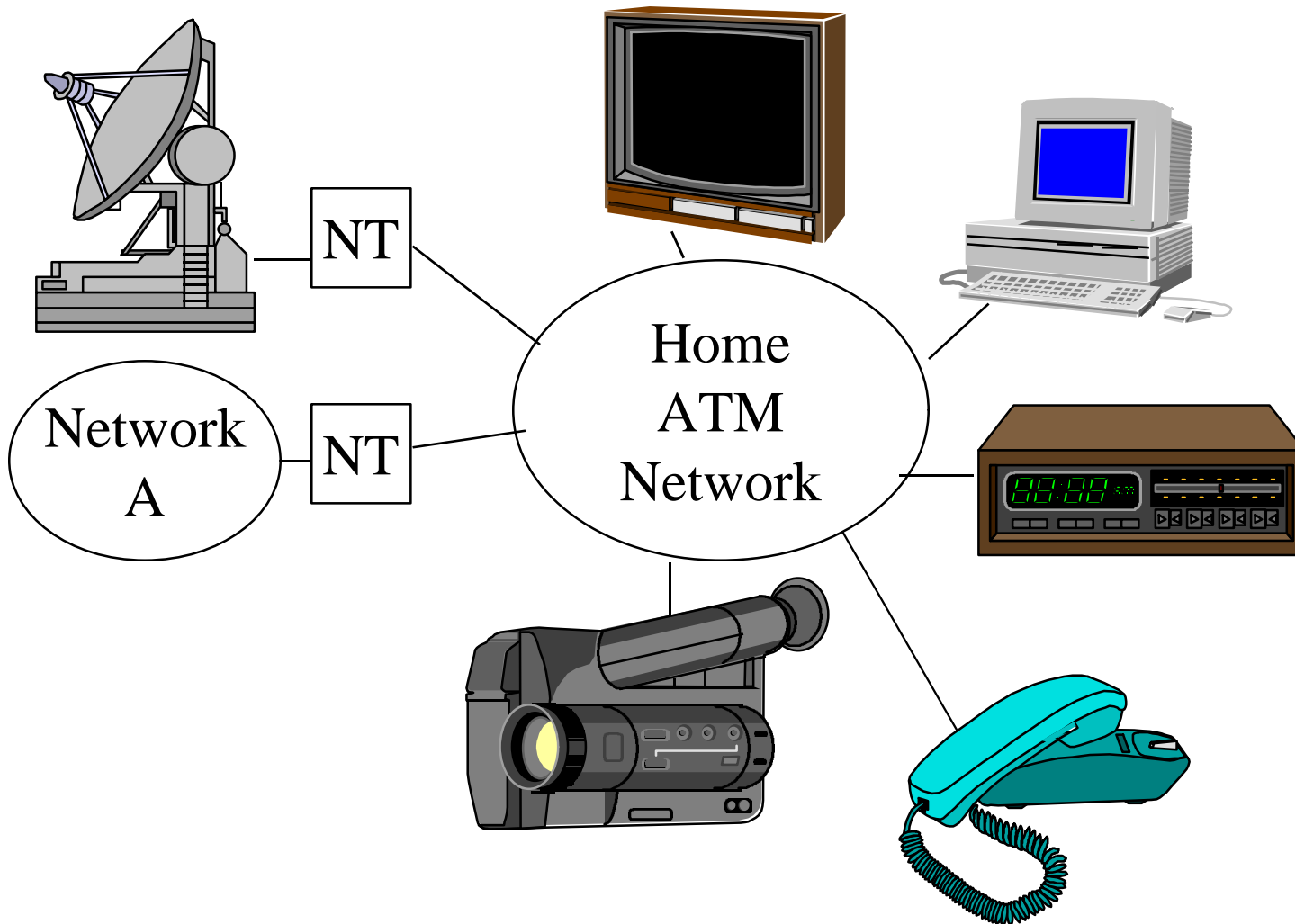


All ATM

IEEE 802.14 Issues

- q ATM based?
- q Which forward error correction algorithm?
- q Size of slots?
- q Upstream sharing requires ranging of homes. How precise?
- q Security and encryption
- q Error handling by MAC
- q Station addressing

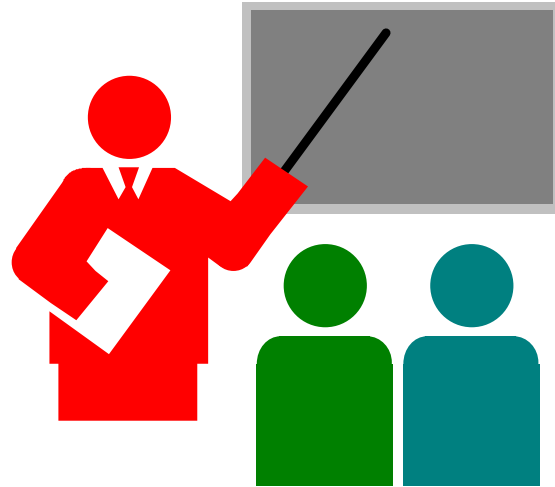
Home ATM Network (HAN)



Home ATM Network

- q Allow intra-home device communications
- q Access network not required for intra-home communications
- q 20-50 Mbps, symmetric, full-duplex
- q Reach of 50 m
- q At least 128 addressable devices
- q Position independent operation
- q Allow firewall between HAN and access network

Summary



- q High Speed Access to Home:
HFC, FTTC, FTTH, ADSL, VDSL
- q 6 to 155 Mbps downstream, 1.5 Mbps upstream
- q Both cable and telecommunication companies are trying to get there with minimal modification to their infrastructure

Acronyms: RBB

- q ADSL Asymmetric Digital Subscriber Line
- q ANI Access Network Interface
- q CATV Cable TV
- q EMI Electromagnetic Interference
- q FTTC Fiber to the curb
- q FTTH Fiber to the home
- q HAN Home ATM Network
- q HFC Hybrid Fiber Coax
- q NT Network termination
- q ONU Optical network unit

- q **STB** Set top box
- q **TII** Technology independent interface
- q **VDSL** Very high speed digital subscriber line
- q **VOD** Video on demand

References: RBB

- q L. Wojnarowski, "Baseline text for the Residential Broadband Working Group," ATM Forum/95-1416R3, June 1996.
- q L. Wojnarowski, "Requirements/Criteria for Residential Broadband," ATM Forum/95-1397R5, June 1996.
- q T. Kwok, "A vision for Residential Broadband Services: ATM to the Home," IEEE Network, September/October 1995, pp. 14-28.
- q M. Laubach, "To Foster Residential Area Broadband Internet Technology," ConneXion, December 1995, pp. 18-30.

- q D. Zgodzinski, "The Cable Chase," Internet World, June 1996, pp. 63-66.
- q "Cable Modems Frequently Asked Questions,"
<http://www.cox.com/modemfaq.html>

References: IEEE 802.14

- q IEEE 802.14 working group,
<http://www.com21.com/pages/ieee-802.14.html>
- q IEEE 802.14 WG, "Cable-TV Functional Requirements and Evaluation Criteria," IEEE 802.14/94-002R2, February 1995.