# Network Interface Unit, A Broadband Gateway Into The Home

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*Abstract*

*Cable has been promising two-way services since the early 1970s, but only recently have significant numbers of Cable plants upgraded to full operational two-way.*

*Requirements are presented for Network Interface Units (NIU) in two-way HFC networks that are deploying or plan to deploy blended services*[i]*. Numerous attempts to deploy NIUs, mostly for broadband Conditional Access, have traditionally not been very successful. An argument is put forth which encourages Cable to use NIUs to effectively deploy telephony and to use them to secure a beachhead against competition.*

*The What, Why, and How of deploying NIUs is discussed as well as several of the benefits, options, and problems to overcome.*

## INTRODUCTION

Competition is the raison d'etre for NIUs. Competition for the established Cable companies comes from overbuilders, the Local Exchange Carriers (LEC), and the Competitive Local Exchange Carriers (CLEC)[ii].

Overbuilders are differentiating themselves from the established Cable companies, by being more aggressive and deploying more of the new services, such as digital TV, Cable Modem, and cable telephony quicker. The LECs are capitalizing on their Carrier Class networks, their anticipated higher security, the world wide ubiquity of their lines, their dominance of the commercial telephony market, their deep pockets, and their ability to bundle telephony and high speed data in a single line.

Market analysts are projecting revenues for high speed data services, from Cable Modem, to be from $11.9 billion [1] to $26 billion [2], by 2003[iii]. Cable telephony could reach 9 million[iv] subscribers by 2003, at an average of $35 per month, representing additional revenue of approximately $4 billion. The projection for Cable's video revenues for 2003, is about $38 billion. Clearly, cable data and telephony represent considerable incentives to attract competition and venture capital.

Most current Cable telephony deployments are for switched rather than packetized telephony. This is due, in part, because the PacketCable specification is not complete. But, analysis demonstrates that even at the highest scales of economy, the total price per subscriber for the IP solution is about half of that for the circuit switched solution. The price gap is even larger when there are only a few subscribers on the network. This suggests that IP telephony would be the natural tool for CLECs and overbuilders to compete against the local telephone companies, and eventually against Cable's high-speed data and telephony offerings.

## WHAT IS AN NIU?

Definition : A Network Interface Unit (NIU) is a physical enclosure, located at the service endpoint, which connects between the

HFC network and local residential wiring. It establishes a point of demarcation between the HFC network and the subscriber premise and may include a variety of functional elements.

The NIU demarcates, or clearly separates the HFC network from the subscriber's network, and consequently demarcates the Cable operator's area of responsibility from the subscriber's. Although the concept of an NIU can be used in traditional non-HFC networks, the NIU is more suitable to the evolving HFC network architectures. HFC was invented to exploit the broadband nature of Cable. It has done very well for traditional one-way services for the past decade, but its real purpose was to encompass two-way services. Because two-way services were not widely available when HFC was deployed, (the Internet was just beginning to emerge, telephony wasn't even legal in most states, interactive TV was faltering), NIUs were not seriously considered as an necessary part of HFC networks. But in today's competitive environment, NIUs and network powering need to be an integral part of new HFC network architectures.

To be an effective network element the NIU needs to be more than just an RF interface device. It can easily play a roll as part of the distributed intelligence of modern HFC networks.

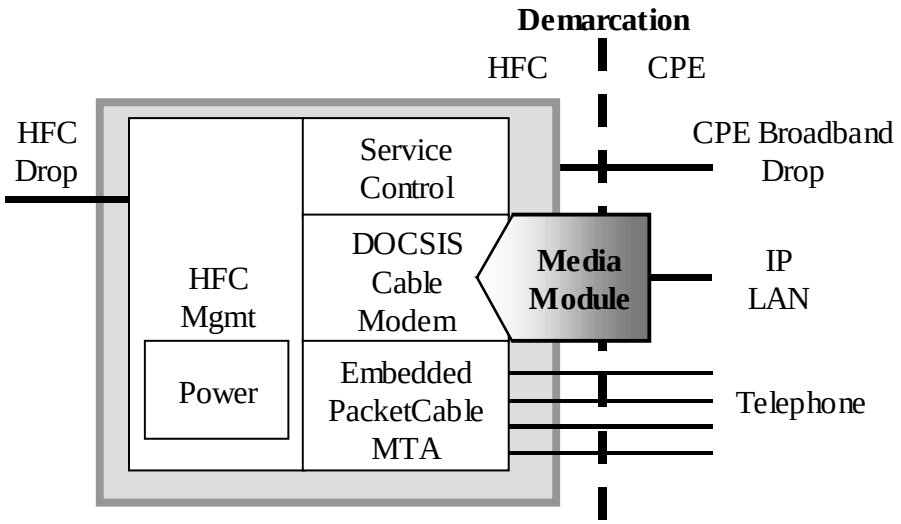


Figure 1: NIU Major Components

NIU Components

- HFC Management: terminates the coaxial cable. It separates the RF signal into three components:
  - 50MHz to 860+ MHz (downstream)
  - 5MHz to 42 MHz. (upstream)
  - DC to 1 MHz. (power plus status)

  Additional Management Functions:
  - status monitoring of;

  - NIU modules,
  - power usage,
  - the subscriber's upstream RF, and
  - other non-time-critical parameters
- control of upstream RF, from the subscriber, and downstream RF to the subscriber
- control of average power usage
- other low speed data functions, such as meter reading, load shedding, etc.

- Service Control provides demarcation of the RF, going to and coming from the subscriber. It functionally:

  - controls upstream impairments from subscriber's network ( e.g. RF drop), with an On/Off switch or filters
  - turns downstream services On and Off
  - allows a variety of conditional access control modules for analog and digital services, e.g. de-scrambling, traps, jammers, and whatever clever contraptions the vendors can conceive.

Digital television and Open Cable present the same interfacing problem Cable has faced since the introduction of the first converter, Cable has more functionality than standard TV receiving devices provide. The QAM is a prime example of this trend. The 64/256 QAM, chosen by Cable, is not compatible with either current TV receiving devices, or future digital TV receiving devices, since 8VSB has been chosen as the North American broadcast standard for digital transmission. Even if digital TV receiving devices were equipped with 64/256 QAM receivers, the legacy NTSC and non-QAM receiving devices will predominate well into the future. In the near term, it appears that Set Top Boxes (STB) will be with us for some time, at least in the initial phases of digital TV. One possible solution is to add a Gateway, in the home, which would work together with the NIU. The Gateway would control all of the Home Networks and do all of the necessary protocol and signal conversions between Cable's digital TV signals and those required by digital and/or analog TV receiving devices.

Some of the ways that an NIU can alleviate the Cable network/ CPE device interface dilemma are that the NIU:

  - controls service access to the Gateway, for all TV channels (both digital and analog)
  - shares circuits, (such as the Out Of Band modem), when there are multiple TVs in the home
  - does analog conditional access at the demarcation point, so that this feature is not required in STBs or gateways (this is best done in the NIU so that subscribers don't have direct access to conditional access).

- DOCSIS Cable Modem, as an optional embedded element of the NIU, has key system advantages:

  - Cable Modems have an Ethernet bus, which can support multiple PCs in the home. All that is needed is a twisted pair from the NIU (or a wireless LAN) to each device that uses a data connection. Multiple Cable Modems can be added for MDUs and enterprises.
  - it is always active, because of the lifeline feature, and is used for monitoring intrusions and hack attacks
  - it can also be used in non-DOCSIS modes to assist in HFC network performance monitoring and control.

- PacketCable MTA is the CableLabs interface, from Cable Modem to standard analog telephones. It is specified to have four twisted pair analog lines. If a Cable Modem is included in the NIU, it is logical to include the embedded MTA to save a truck roll when the subscriber wants cable telephony.

  – the MTA was created to attach to the Ethernet bus of a Cable Modem located near a PC. But there is rational to embed the MTA in the NIU, where twisted pairs to phones terminate
  – each of the four lines can be provisioned remotely from the OSS, no truck rolls.
  – one of the lines can be provisioned to carry HPNA for other data services.

- Media Module (MM)

  – The MM takes the IP output from the Cable Modem and converts it to other standard interfaces, e.g. 802.11 and Bluetooth wireless, HPNA, etc.
  – a standard interface, such as PCMCIA is used to allow a variety of options offered by several vendors.
    – the PCMCIA interface may make more sense in a Gateway[v] in the subscriber's residence, so that the subscriber has easy access
    – in this case, the Ethernet, IP line, can be brought to the Gateway
  – it only makes sense to add the MM to an NIU if it is more cost effective than adding a Gateway.

- Power is one of the critical elements, and problems, of NIUs. Operators are requesting 5 watts or less of average power consumption (3 watts in some cases). Their concern is the cost of power, which is significant when there are thousands of NIUs deployed.

  NIU power:

  – Lifeline service[vi] is required for primary line telephony
  – For lifeline service, network power is

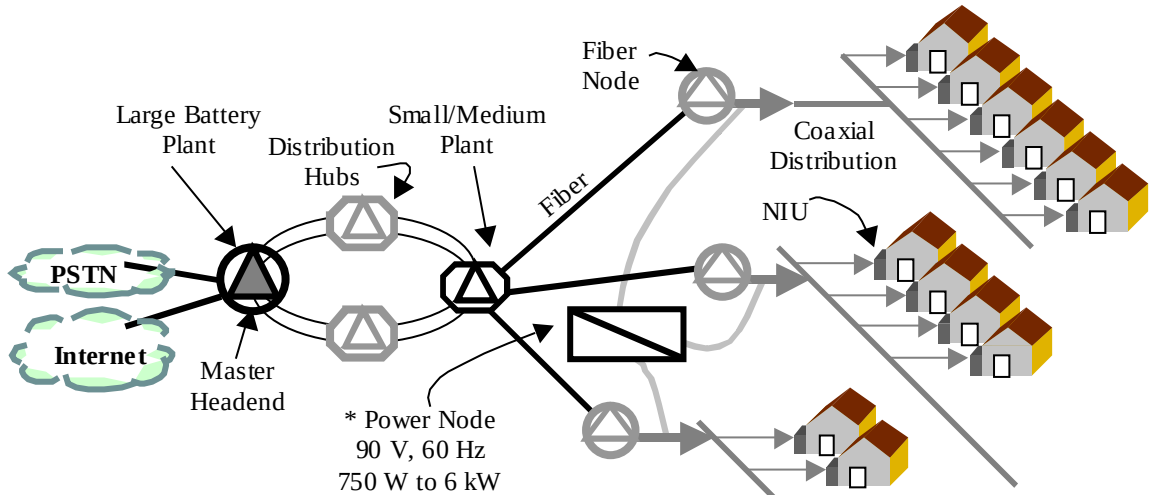


Figure 2: Gratuitous Cable Network Power Architecture (Centralized Network Power)

more cost effective than batteries at the NIU, when penetration of telephony exceeds about 10%.

- NIUs can be normally powered from the home and seamlessly switched to the network power when home power is lost
- New power distribution architectures are evolving for Cable (Figure 2)
  - these new architectures will have status monitoring and control capabilities, which could lessen the burden of CMTSs to support similar functions

Operations and Maintenance (O&M)

A means is provided to provision an NIU, even if there is not an embedded Cable Modem or the Cable Modem has not yet been initialized. An Out Of Band (OOB) modem is used either to work, as the Open Cable OOB channel, or over the cable network power system, using power line transmission standards.

Provisioning includes functions such as:

- Initial installation of NIU,
  - NIU arrives fully tested and configured with all security mechanisms ready
  - NIU is installed in a convenient location for service and if possible, close to telephony and power.
  - before installation
    - subscriber has prepared all networks and wiring
    - Cable operator could use a separate group that does wiring installations
    -
- Changing and ordering services (basic, pay, data, telephone)
- Service and maintenance of NIU and subscriber's account

Securing the Service

The NIU's primary security feature, it is out of reach and not easily tampered with by the subscriber. It has tamper alarms that indicate attempted tampering, either with the HFC drop cable or the NIU. If there is an intrusion attempt, an alarm is sent to the Operations Support System (OSS) and the appropriate action is taken locally within the NIU, (e.g. turn off all services, turn off specific services, inhibit the upstream), to be followed up by the Cable operator's action.

Key security functions:

- NIU is always active
  - tamper alarms
  - continuous monitoring of NIU status and HFC network
  - lifeline functionality for telephone
- Control of subscriber's access to HFC:
  - upstream RF
  - downstream RF
- Modular for easily upgrading or changing services and features by service technicians
- Common X.509 certificate and secret encryption keys, embedded by manufacturer,
  - difficult to clone, because Cable operator knows credentials of all NIUs
  - retail Cable Modems, MTAs, and STBs, still represent a threat, but if there is any suspected attacks, the NIU can block service.

## WHY USE AN NIU?

**Competition**. By installing NIUs, the competition can roll out high speed data and telephony services faster than retail distribution or in-home boxes. And the NIUs provide a more secure environment and a well-behaved cable plant. NIUs are a key network element for competing in the high-speed data and telephony businesses.

- High speed data and telephony are profitable businesses in their own right and are a good way to gain new revenues (about $ 20 billion by 2003).
- DOCSIS and Packet Cable standards offer an attractive opportunity for CLECs and Cable overbuilders
- End-To-End IP telephony is substantially less expensive to deploy than the standard switched telephony approach, making it easier to compete with established telephone companies using switched technologies.
- The battle for the subscriber's data business could well hinge on the telephony offering.
- Since PacketCable telephony requires a DOCSIS Cable Modem, it makes sense to deploy NIUs with these devices installed
- LECs hold the edge in telephony, with carrier class networks, business experience, and worldwide presence. When they get their high speed data act together, they will be a formidable competitor.

Even though the Cable Modem and MTA are planned to be available through retail and supported by several MSOs, there are good system reasons for including these devices in the NIU. An NIU provides three important HFC network functions, essential for telephony and effective high-speed data:

- Network integrity,
- Operations and Maintenance,
- Service access control.

### Network integrity

- Access and throughputs for Cable Modem upstream traffic are increased because impairments generated in the home do not get into the HFC upstream. These can come from:
  - RF leakage; from TVs, VCRs, and STBs.
  - motors and cordless phones,
  - computers and other digital devices
  - disconnected coaxial drops dragged across the radiator

- Hackers don't have direct access to the HFC network
- High peak levels of upstream transmitter bursts, (from Cable Modems or STBs in the home), will cause clipping in the upstream laser. Harmonics are generated which can affect the full 5 to 42 MHz spectrum. This can be detected and controlled by the NIU.

### Operations and Maintenance (O&M)

The key to O&M is to reduce truck rolls:

- is conveniently located for service access.
  - typically external to the residence
- has status monitoring and control functions,
- is modular for easy upgrading ,
- has tamper alarms

### Service Access Control

Cable now can offer a broad array of services to the subscriber. All of these services require access control, not only for the distribution of downstream services, but also controlled use of the upstream, where bandwidth is scarce and the spectrum needs protection.

It is more difficult to secure services in the subscriber's home, without an NIU:

- the devices can be powered off, so that the devices can not be continuously monitored for tampering, as can be done in the NIU
- encryption keys and certificates are not in a trusted environment.
- cloning threats, which can be reduced for in-home units as described in [3], still extorts a considerable burden on the CMTS

There are several attacks a hacker can launch against data and telephony services:

- Disruptive Attacks - inject impairments into the network to disrupt service,

- Mild Attacks
  - sniff the downstream to learn when other Cable Modems are scheduled to transmit, and jam their bursts with the intention of gaining more bandwidth
  - get your own map information, but jam other modems form getting their information in the downstream

- Sophisticated Attacks
  - clone Cable Modems, MTAs, and STBs
  - use authorized Cable Modems to steal service:
    - jam the downstream so that Cable Modems begin searching for another downstream frequency.
    - the hacker then inserts their own downstream channel, and begins to initialize other Cable Modems, bypassing security.
    - once initialized the rouge CMTS can then download new software to the unwary Cable Modems .
      - with the new software, the hacked Cable Modems can now be directed to send data to the hacker's CMTS, or to process any requests the hacker has for data.

## HOW TO IMPLEMENT AN NIU

How to provision an NIU, when it is initially installed, is a matter of strategy. Not every subscriber needs an NIU initially. It is only needed in those nodes that have telephony or Cable Modem subscribers. What to put in the NIU, is also a matter of strategy. The basic elements are all required for network integrity, but different flavors of each element can be implemented. If the NIU and its interfaces are standardized by the SCTE, a variety of vendors will be available to supply modules.

Installing the Cable Modem and MTA in every NIU, is primarily a cost and powering issue. If the Cable Modem is deployed in the NIU, the MTA might as well be added too, because it is a modest cost-up. The cost will likely be offset by a simplification of provisioning, (e.g. reduced truck rolls), when the subscriber eventually decides to try Cable telephone service.

Semiconductor vendors are continually integrating more functions into less chips with smaller geometry's. Soon a single chip that does a complete Cable Modem and MTA

will be available. A logical argument could be made to include the Cable Modem and the MTA in all NIUs.

- HFC Network Interface includes:
  - diplexer for separating the spectrum:
    - 40 to 90 VAC power
    - power line modem (status and control)
    - downstream (50 - 860+ MHz.)
    - upstream (5-42 MHz.)
  - embedded Cable Modem (5 to 860+ MHz)
  - Low Noise Amplifier (LNA), *optional*, to improve the noise figure of the downstream RF.

- Power supply
  - operates with network power (40 to 90 V, 60 Hz)
  - or 110 VAC home power
  - primary power is software selectable from either network or the home.
    - when primary power is from the home. Network power is seamlessly activated when home power is lost (Lifeline capability)

- Status, monitor and control
  - powerline modem is used (e.g. CEBus spread-spectrum modem)
    - alternatively Open Cable Out Of Band (OOB) modem, or Cable Modem could be used
  - monitored parameters
    - power usage and status
    - subscriber upstream power and impairments
    - NIU functional status (all modules)
    - downstream status (requires Cable Modem or status monitoring plug-in for downstream processing module
    - tamper alarm
  - controls
    - downstream service control (On/Off, conditional access)
    - upstream control (On/Off, filter adjust)
    - Cable Modem disconnect/connect

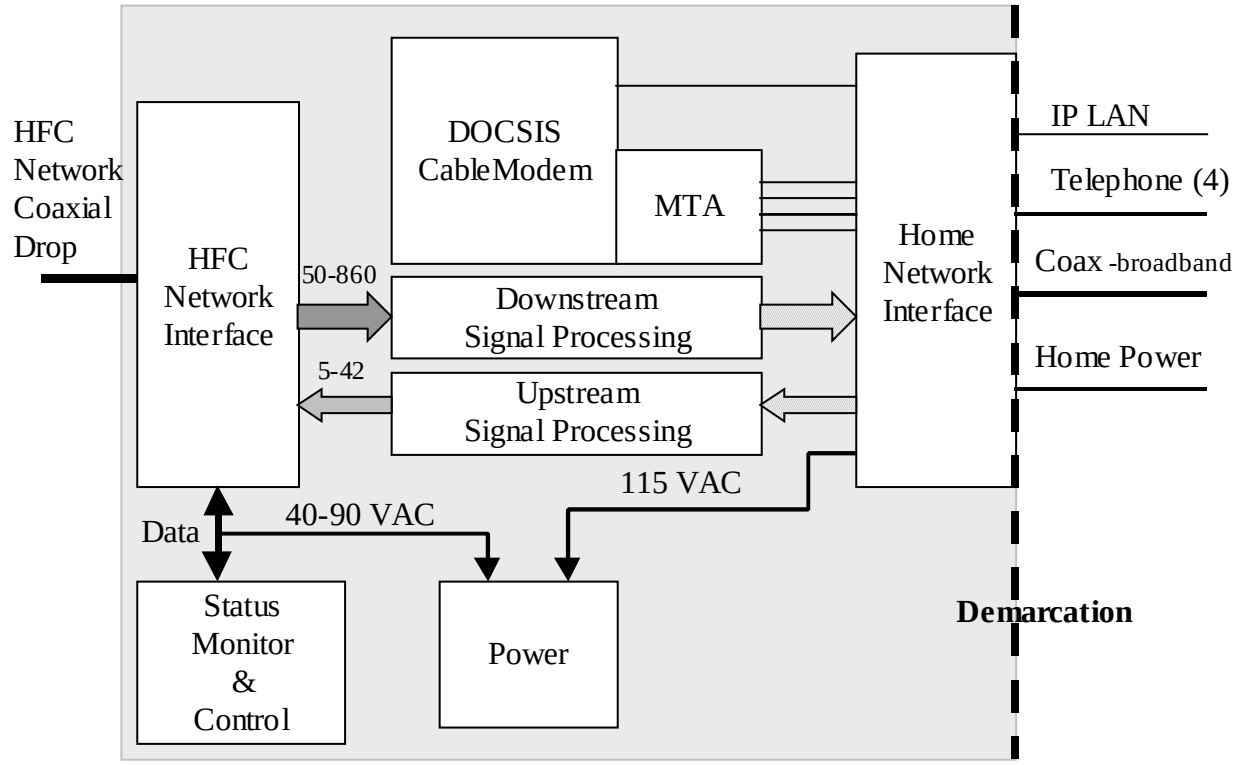


Figure 3: NIU Architecture - Typical Implementation

– NIU master reset

- Downstream processing

A simple embodiment includes:

– service On/Off switch
– Broadband amplifier, with digitally controlled output level
– diplexers

Provisions are made to incorporate additional functionality by using plug-in modules:

– filters and traps
– tuners
– analog descrambler
– other conditional access technologies

Downstream processing could also contain QAM demods for digital TV

- Upstream processing

Basic functionality includes an On/Off switch and upstream power level detector

Other plug-in modules could:

– filter specific upstream channels

- Embedded Cable Modem and MTA

There are several advantages to including the DOCSIS Cable Modem and the Packet Cable components in the NIU:

– the data and telephony modules will be isolated from any impairments generated in the subscriber's RF network
– a higher level of security is achievable because, the Cable Modem can always be guaranteed to be active.
– cloning attacks described in [3] are not a serious problem, because the subscriber doesn't have access to either the embedded keys or certificates. And with tamper monitoring in the NIU, any attempt to gain illegal access to the NIU will result in an alarm being transmitted to the OSS and a possible disconnection from service.

- Home Network Interface (+Media Adapter)

There are four primary interfaces into the home, from the NIU:

– coaxial drop, feeds any TV receiving devices or Cable Modem devices
– IP Ethernet, either 10BaseT or 100BaseT is available
– four twisted pair standard analog telephone lines
– home power (optional)

The Media Adapter allows other interfaces into the home:

– Home PNA, Cable Modem data is multiplexed with one of the analog lines
– PCMCIA, allows Cable Modem data to interface to several transport interfaces such as IEEE 802.11 wireless.

Enclosure:

There are several challenges for housing the NIU functions, including:

- Environment
- Heat dissipation
- Component access
- Security

High tech plastic has been effectively used to deal with typical environments that the NIU will encounter.

The use of multilayer polymer structures, for the enclosure allows taylor-made properties meeting a wide range of requirements for the NIU. Plastics can be made to meet the stringent requirements of an NIU, but are much lower in cost than similar metal enclosures. For example, an enclosure consisting of a multilayer sandwich structure can be made particularly suitable for NIUs used outside. Structures can be made to exhibit excellent long term weatherability and UV stability, good impact properties, (even at temperatures below -40 degrees centigrade), and good chemical resistance.

Heat dissipation is a major problem when designing low cost electronic enclosures for outdoor environments, particularly those Arizona summers. A common approach is to put a large heat sink on the back of the NIU to dissipate the heat. This approach can be expensive and makes for a heavy NIU. New tools for meeting the challenges of outdoor environments are becoming available. Semiconductor technologies, such as silicon-on-insulator, are currently used to make Cable tuners covering the Cable spectrum to 860+ MHz. The typical operating range exceeds 85 degrees centigrade. Other high tech means to absorb or dissipate the heat from NIU components, such a heat absorbing gels and forced ventilation techniques, are being tested. The problem is still waiting on an elegant solution. Fortunately there are many solutions currently being developed, not only for Cable, but for NIUs deployed for telephony and other equipment such as cellular base stations.

Component access provides security, determines the ease of provisioning and servicing, and the flexibility to upgrade. It would be a major advantage to the Cable industry, if it were to turn its standardization efforts toward standards for NIUs and NIU plug-in modules.

Two types of standardized modules are needed. Analog RF modules, which plug into an RF bus and digital modules which use a standard data bus, such as the PCI bus. All modules should be plug-and-play at the cable network level so different configurations can be easily changed or upgraded by service personnel working in conjunction with the OSS.

The downstream and the upstream signal processing are separated in the NIU and each is processed independently. The upstream processing has the capability to turn off the upstream or filter impairments from the Home Network. The downstream has a wide band amplifier to compensate for losses incurred by the Home Network. Additionally, conditional access technology for the analog and/or digital channels can be added, depending on the Cable operator's preferred implementation. Various types of conditional access technologies are available in the market, and could easily be adapted to the NIU if standardized interfaces are defined by the industry.

Status Monitor

A key NIU element is the status monitor and control modem. This is used for provisioning (activating / deactivating conditional access, supporting plug-and-play capability), monitoring the status of the upstream, downstream, and key elements of the NIU.

Power

And finally a means of maintaining power in the NIU, even if the power is lost in the home. This only critical when cable data and

telephony services are deployed, to be able to provide the lifeline capabilities provided in primary line telephony, and may not be needed for NIUs that only provide an RF demarcation. The NIU can be powered from the home, but when there is a power outage in the home the HFC network should provide the power, seamlessly, with no interruption of service. This power could be, and is currently, provided by batteries located at the home, but when the service penetration is greater than 10%, network powering becomes less expensive than the cost of the batteries, not to mention the ease and cost of maintenance.

## CONCLUSION

Ten years from now, 2010, virtually all HFC networks will have NIUs. That is a pretty strong statement, but operators deploy HFC for their ability to provide blended two-way services. Telephony could be the trump card that captures the high-speed data subscriber. This could be a likely scenario because, Cable has three strong competitors, LECs, CLECs, and overbuilders[vii] who will push for combined telephony and high-speed data services. As competition intensifies, over the next few years, NIUs will be required to be able to manage the HFC networks efficiently and to enable the deployment of new services and innovations rapidly.

## REFERENCES


[1] Research group Kinetic Strategies, (11/99)
[2] IDC report (12/99)
[3] Medvinsky, Sasha; Anderson, Steven, "DOCSIS Security vs. Cable Modem Cloning", Conference on Emerging Technologies, January 11-13, 2000, Proceedings Manual.
[4]Jones, Doug, "PacketCable Security Overview", Conference on Emerging Technologies, January 11-13, 2000, Proceedings Manual.
[5] Burroughs, Robert, "A Point of Entry Interface for 2-Way Broadband Information Delivery", June 7, 1993, NCTA Cable '93 Proceedings Manual.


## ACRONYMS

| | |
|---|---|
| CLEC | Competitive Local Exchange Carriers |
| CMTS | Cable Modem Termination System |
| CPE | Consumer Premise Equipment |
| DOCSIS | Data Over Cable System Interface Specification |
| HPNA | Home Phoneline Networking Alliance |
| LEC | Local Exchange Carrier |
| LNA | Low Noise Amplifier |
| MM | Media Module |
| MTA | Multimedia Terminal Adapter |
| O & M | Operations and Maintenance |
| OOB | Out Of Band |
| OSS | Operations Support System |
| PCMCIA | Personal Computer Media Communication Interface Adapter |
| QAM | Quadrature Amplitude Modulation |
| RF | Radio Frequency ( > 5 MHz) |
| SCTE | Society of Cable Telecommunications Engineers |
| VSB | Vestigial Side Band |

NOTES

[i] Blended service, is a term that is currently in vogue to describe the new services that will be introduced when the PacketCable standard is implemented. It includes, high-speed IP data, IP telephony, streaming video, digital and interactive TV. With PacketCable, all of the services tend to blend together.

ii CLEC, sounds like a tribe out of Star Wars. But, they are entrepreneurial companies that are competing with local telephone companies for the local telephone business. They're typically very aggressive and looking for every avenue to compete.

[iii] Cautionary note: Kagan, Q1 99, projected Cable's high-speed data revenues to be only $3.8 billion by 2004. But, with Cable modems reaching more than 2 million units by 2/2000, this number appears too low, if you assume an average 1 month rental of $40.

[iv] Typical number, at high end, from several sources: Forester 2/99- 9.1 million, Goldman Sachs 7/99 - 9 million, Kagan 6/99 - 5.8 million

v The term Gateway usually refers to a device that passes traffic between different protocols, such as between Ethernet and Bluetooth protocols. The term gateway is used in its generic context, in the title of this paper, to mean the door between the subscriber's Home Network and the HFC network.

vi Lifeline power: power is available to make telephone calls even if there is no power in the residence.

[vii] since the Internet represents a huge opportunity, there are more than the four major players looking to gain market share: satellite, wireless - PCS and broadband.