The Residential Gateway—A New Traffic Cop for the Home

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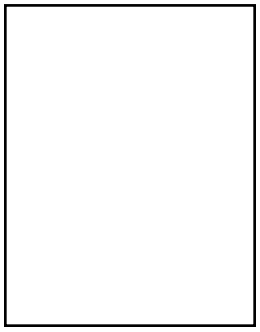

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Around the world, deregulation of the telecommunications industry is resulting in competition among telephone carriers, cable TV services, utilities, and other newcomers. One effect of this competition is the sudden emergence of not one, but several actual and potential broadband communications networks into homes and small businesses. This was spurred initially by the goal of interactive video services. In the last year, however, it has been shown that interactive video will not, by itself, pay for the infrastructure investment. Other services must be provided over these broadband residential access networks in order to justify the investment. These services include high-bandwidth access to the Internet and to private networks, voice telephony, electronic games, home automation, home security, utility monitoring and control, and many other as yet unimaginable applications.

For the last several months, a group of individuals from a variety of firms involved in the development of the network of the future has initiated a new concept that is a basic enabler for that network. This concept is so important to the realization of a multiple provider, competitive, residential environment, that it is necessary. Otherwise, that envisioned future will have no realistic chance of occurring. This concept has been dubbed the "Residential Gateway." It is similar, in part, to other work that is going on in various standards bodies, such as the Digital Audio-Visual Council, ATM Forum, EIA, Video Electronics Standards Association, and IEEE 802.14.

The Residential Gateway is not meant to compete with, but rather integrate into, these implementation groups. However, the Residential Gateway concept uncompromisingly takes the position of the consumer in viewing and ultimately interacting with network services. Also, this approach is dedicated exclusively to residential requirements, rather than compromising those needs with business and institutional concerns. The Residential Gateway is intended to be a "customer-centric" device; it is intended to place the customer in the center of network planning efforts.

The Residential Gateway Concept

To understand what the Residential Gateway concept is all about, let's step back and consider what is (broadly speaking) proposed for the near future. Several different networks to the home are planned. These will include the existing twisted pair, telephone network, and the coax (and fiber) CATV networks. In addition, there will be, not all necessarily at the same place and same time—although that coincidence is not precluded:

- DBS networks.
- Hybrid fiber/coax networks.
- Fiber-to-the-home networks.

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- ADSL networks.
- ATM networks.
- Switched digital video networks.
- PCS networks.

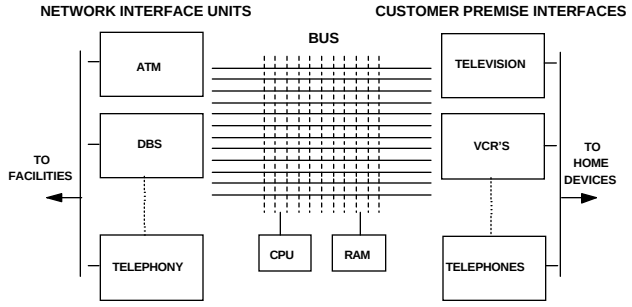
Not only are these competing networks, they are incompatible at various levels of the OSI model (i.e., they are incompatible in more than their basic physical interface characteristics).

This incompatibility and the competition (among the networks in functions, price, availability, and in other areas) mean that, ultimately, residential customers will be faced with the prospect of dealing with a very complicated multi-node switching problem. These same customers have trouble programming a VCR—surveys indicate that up to 70% of adults in fact can't program a VCR. It is inconceivable that they will be able to deal with this problem. If they cannot, there are only two options:

- Give up the stated model of the future, which is unrealistic because it is already beginning to be put in place.
- Devise a technology solution that will handle this function and hide the complexity from the consumer.

The Residential Gateway is an answer to this dilemma. It inserts a control function between external networks and in-home networks and devices. The Residential Gateway serves as a "traffic cop" function—controlling and routing traffic so as to allow maximum use of all facilities (see Figure 1).

Figure 1
Residential Gateway System Layout



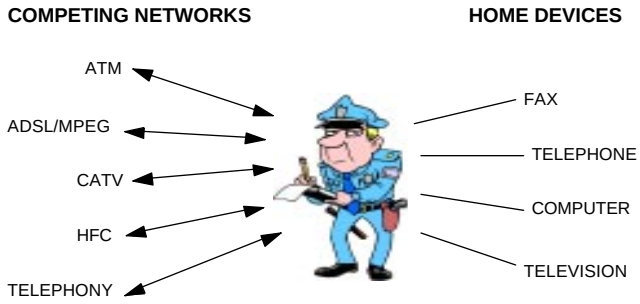
Source: B&C Consulting Services

Hiding the Complexity

The idea of the Residential Gateway, then, is to hide all of this complexity from the consumer and perform the needed functions in the background, similar in concept to the devices now available to automatically program VCRs. The Residential Gateway provides an intelligent device capable of terminating all the proposed networks bound for the home. It is also capable of terminating all of the in-home networks (twisted pair, coax, X-10, security, HVAC, data/LAN, audio, video, etc.), and provides for seamless (and painless) interconnections between inside and outside networks as well as providing a user-friendly control interface. Ultimately, it allows customers to operate in-home devices over the network(s) of their choice, at the highest level of functionality, and without concern as to the switching and interface complexities involved.

The Residential Gateway achieves this by an adaptation of the classical PC design. A bus connects Network Interface Units (NIUs) and Customer Premise Interfaces (CPIs). NIUs are installed on a one-for-one basis to match the desired incoming networks. Thus, examples of such NIUs are ATM, DBS, telephony, and CATV. In the same fashion, CPIs are provided to match the devices—TVs, VCRs, telephones, and computers—providing the services desired in the home (see Figure 2).

Figure 2
The Residential Gateway as a Traffic Cop



Source: B&C Consulting Services

All material is converted to digital to cross the Residential Gateway bus. On the home side, the material is converted back to analog if necessary. Eventually, all material coming into the Residential Gateway will be digital and will require no A/D

conversion. The Residential Gateway, therefore, is thought of as a bridge device that will allow us to gracefully move from today's networks and devices to tomorrow's.

In today's world, the Residential Gateway is possibly an overkill, although some of the desirable multiple device capabilities would be very hard and expensive to achieve in currently-available ways. However, in the evolving world of multiple networks with multiple protocols providing source material for these home devices, the Residence Gateway will be a necessity, not a convenience. It will hide the complexity of the multiple sources to multiple (and incompatible) sinks problems.

Current Migration Steps Leading to Convergence of Local Networks

In terms of the home delivery network, CATV networks and telephony networks have been converging through recent developments. It would be possible to trace the migration of each of these networks in their respective timeframes, but that material should be familiar to most readers of this article. The important point is that, from a structural view, both networks are moving strongly in the same direction. These two networks will also cause all of the above-mentioned newcomers to migrate in the same direction. This direction of migration is shown in Table 1.

As can be seen, the migration is toward the customer in terms of every parameter. The movement is also toward more fiber (i.e., toward fiber going deeper in the loop) and toward more digital circuits. At the same time, the network intelligence also moves toward the customer. Results of this migration are indicated in the similarity of architectural drawings that are produced by the telcos and by the major cable MSOs. If the labeling were changed (for example, "CO" to "headend," and "remote" switches" to "neighborhood hubs"), the drawings would be virtually identical.

Table 1
The Parameters of Network Migration

	From	To
Transmission Path	Copper (twisted pair or coax)	Fiber
Transmission Type	Analog	Digital
Electronics Location	Network (COs or headends)	Toward Customer (remote terminals, neighborhood feeds, etc.)
Intelligence	Network	Toward Customer

Source: C. Holliday

How Does the Residential Gateway Fit in This Migration Pattern?

The Residential Gateway fits this migration toward the customer in two ways. First, of course, it could be viewed as the ultimate move toward the customer, with fiber terminating on the Residential Gateway at the customer's location. Second, it provides that element often overlooked in broad views of network architecture—the bridge device. The Residential Gateway will provide a very graceful way to allow analog and digital networks to coexist. Also, it will allow fiber and copper (of various types) to coexist. When the final move to fiber and digital (or maybe to fiber and some analog and then fiber and all digital) is made, the network card is replaced in the Residential Gateway and everything else is ready.

The move of the intelligence to the customer is somewhat more subtle, and it is not so parallel between the telephony and the cable worlds. In the telephony world, this movement has followed the move of the first switching point out of the COs and toward the customer, although this has not been a completely parallel movement either. The first remote switching devices were very "dumb," depending on the COs to provide the necessary intelligence. As memory and processors vastly improved their price/performance ratios and as the advantages of customizing became apparent, the intelligence also moved with the switching.

In the case of CATV networks, in one sense, they have always had the intelligence at the customer's location. That is where the tuners were—and are. However, as they have begun adding various types of switching (commercial headend ties, switched digital video, near video on demand, and video on demand), their networks have begun looking like the telcos in this respect also.

The Residential Gateway puts the last network intelligence point at the customer's location. This ultimate step in the movement of the intelligence has

many implications. Most important, it is the key to bringing the customer to the real center of network design. The placement of this intelligence at the customer site offers the opportunity to literally customize each customer's telecommunications services based on his/her desires, tastes, and home equipment. It also allows for rapid change by the customer in either the network delivered services or in the home devices or in both. In addition, it creates functionality by allowing the customer much greater flexibility in using combinations of devices and network-delivered services.

"Next Steps" in Residential Gateway Development

The Residential Gateway is by no means a finished product. It is still very much in the concept stage. Work has begun on many fronts (in the standards bodies, at interested manufacturers, and in the labs and test beds of interested carriers) to extend the concept to prototypes and ultimately to products. Some of the important next steps in terms of technology evaluations and decisions are as follows:

Bus Selection

The first requirement for the bus selection is the ability to provide sufficient data transfer capability (from NIUs to CPIs) to allow the coexistence of the envisioned services. The highest bandwidth requirements for the backplane will thus be determined by the need for video services, which require vastly more data transfer than any other service.

In addition to a bandwidth requirement that will handle at least 200 MB (four lightly-compressed video signals), the backplane must be robust and of a proven design with full expectation of long-term support. It must also provide for a sufficient number of expansion slots to allow the Residential Gateway to be useful in the home.

Some of the industry standard interface buses used for PCs, both current and emerging, will fit the requirements. Specifically, PCI (Peripheral Component Interface) and IEEE (Institute of Electrical and Electronic Engineers) 1394 (also known as Firewire) meet the envisioned requirements. An issue with these may be the number of slots that can be used, and it may be that the final designs will require multiple buses. For example, the combination may be PCI for the high-speed requirements and a lower-speed bus (e.g., USB or Universal Serial Bus) for the telephony and low- to medium-speed data.

Processor and Memory Selection

It is desirable that the processor selected be one that is—or will be—in high quantity production to keep costs down and to allow the use of off-the-shelf auxiliary support chip sets. This suggests one of the mass manufactured PC processors. The general requirements suggest that eight MB of RAM memory would be necessary. Because of maintenance considerations, no hard disk is planned.

Operating System Selection

Candidate operating systems include OS/2, OS/9 DAVID, UNIX, Windows NT, and Windows '95. It is very desirable that an off-the-shelf OS be used for the same reasons as an off-the-shelf processor. The OS should be as decoupled as possible from the selection of the processor and the backplane to prevent the risk of standards going in different directions.

Operations Support Considerations

The Residential Gateway concept will result in the maximum amount of hardware being placed in the outer limits of the network(s). To avoid service disasters, it is mandatory that much forethought be given to the issues relating to operations, administration, maintenance, and provisioning (OAM&P).

The deployment of the Residential Gateway will cause millions of intelligence points to be placed in the network, rather than thousands as is currently the case (i.e., in telco central offices and CATV headends), or tens of thousands as would be the case with many of the current architectures for the developing networks (HFC, FTTC, etc.). This situation will require a methodology for two-way transmission of operations data between the Residential Gateway and the network operator's center. It will also require a means at that center to access the individual data streams in order to take appropriate action to individual Residential Gateways.

Ultimately, it is proposed that the Residential Gateway NIUs be compliant with the Telecommunications Management Network (TMN) interface specifications. A new specification (GR-2833) is currently being developed by Bellcore and the standards groups. This specification allows the transfer of OAM&P information between network devices and central systems. This

replacement for TR-303 will move to TMN, and the migration is being planned to be as painless as possible.

Other Benefits

While the Residential Gateway concept is primarily aimed at filling needs for the consumer, it also meets the needs of network operators and device (consumer electronic) designers. The main concern for these latter two groups is in having a standardized interface point for their operations and design efforts. The Residential Gateway will greatly simplify the problem of network and CPE (customer premises equipment) device designers by the standardization of interfaces, while still leaving the opportunity for functional innovation for competitive differentiation.

The development of new services will no longer require that network and CPE developments take place at the same pace. New and innovative end customer services will be achieved by the design of new CPE and, where necessary, by the design of new CPIs (customer premise interfaces—the cards in the Residential Gateway looking toward the home). The addition of MPEG/ADSL, ATM, or other networks will be accommodated by simply adding a network card (NIU) of the appropriate type. With the approach outlined, the full capability of those networks will be available to a wide variety of home devices with full flexibility of use.

Advantages

As noted above, the Residence Gateway concept will provide advantages to customers, network operators, and designers. The following is a list of the more important advantages this concept will provide to each of these groups.

Customers

Reduces set-top requirements. Most American households have over three TVs. The Residential Gateway approach is more cost effective than an expensive TV set-top box, and provides for the future requirements of interactivity. The trend among television and PC manufacturers is to move the digital decompression (MPEG) technology into the device. The gateway represents an opportunity to centralize—and cost reduce—the network interface.

Makes changes (network or services) easy. The Residential Gateway plug-and-play approach provides consumers with the ease of use they demand.

Hides complexity and facilitates multiple networks. The average current home user has a great deal of trouble dealing with currently-available home electronics, evidenced by the 70% of customers unable to program their VCRs. The introduction of multiple, competing networks providing various services will exponentially raise the complexity level. Without a simplifying approach this envisioned future will be a disaster.

Added service options. If an approach that is truly user friendly can be developed, then many more average consumers will be able to take advantage of the vast options that can be made available on these future networks.

Network Providers

Meets analog and digital needs. A single, flexible, extensible intelligent interface is ideal to satisfy both short term "analog" needs, along with high bandwidth "digital" services such as Internet access, HDTV, and services yet to come. The Gateway approach provides this intelligent interface and has many inherent advantages.

Standardizes home interfaces. There is a strong need for standardization of CPE that allows the service provider to flexibly offer new digital application services. The Residential Gateway approach provides a common core set of protocols in a one-box design.

Works with existing business models. Service providers easily can extend their current business model for the gateway approach, and offer emerging technologies and services such as access to the Internet.

Enhances servicing activities. One service provider can perform all security and network diagnostics from the external network interface. The Residential Gateway will be much easier to service and maintain than currently proposed TV set-top box approaches.

Improves remote diagnostic capabilities. The Gateway approach enables remote software diagnostics and extensive network monitoring to be performed, resulting in substantial labor savings in field service calls.

Designers

Defines network interfaces. Currently, device designers generally know the type of network to which a given home device will be connected. For example, a VCR is going to be connected to a network that will provide NTSC signals (or line level video),

even if it comes from a variety of physical sources. In the future, this VCR may need to be connected to an ADSL channel carrying some (MPEG-1, MPEG-2, etc.) compressed signal. The Residential Gateway will provide a standard interconnection for the VCR and will thus eliminate this problem.

Defines home device interfaces. Network designers have the same problem. What will the home devices that will be on the business end of their networks look like? Without a standardized design in the manner of the Residential Gateway, they must guess or provide multiple interfaces.

Decouples network and end device development. Development of network technologies, home devices, and applications technologies are driven by very different forces and on very different timelines. The Residential Gateway concept will decouple advances in one area or the other, thus reducing false obsolescence and increasing advancement opportunities.

Summary

In summary, deregulation and the passage of the telecommunications bill will have a dramatic impact on the U.S. consumer. On the one hand, consumers will see the benefits of technology developments quickly integrated into consumer products. On the other hand, consumers will have to pay for previously-subsidized services, and bear the full costs of bringing this new technology into the home. This influx of rapidly advancing technology will bring great complexity to the home as well as unanticipated costs.

The consumer must be brought to the prime focus of our future network plans. To do so, a standardized interface must be developed for the home. This interface must simplify the control and operations for consumers, while simultaneously allowing them to take advantage of the vastly expanding capabilities of the competing networks. It also must simplify the network operators' and the designers' jobs. The Residential Gateway, as proposed, will achieve these goals, while offering the opportunity to all concerned players to competitively pursue their business plans. The Residential Gateway will, ultimately, lessen the cost burden to the customer through the benefits of standardization, and it will successfully eliminate the complexity. ntq