BLACKSBURG electronic village

Community-based Broadband Telecommunications Infrastructure

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An outreach effort of

Virginia Tech

A university putting knowledge to work

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The Village information servers can be reached
via the World Wide Web at <http://www.bev.net/>

The BEV provides additional information about starting and managing comunity-based networks on the BEV Web site. Check <http://www.bev.net/project/digital_library/> for additional reports and information.

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The BEV is an outreach project of Virginia Tech <http://www.vt.edu>.

Organizationally, the BEV is part of Communications Network Services <http://www.cns.vt.edu>.
CNS is a Virginia Tech department that provides voice, video, data, and related services to the university.

Community-based broadband networks

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Why community-owned broadband infrastructure?

In the 20th century, if a community intended to participate in the Manufacturing Economy, good roads both to and within the community were a critical part of any economic development plan. Privately owned roads were quite common in the United States in the 19th century, but they failed to serve the public interest well. Over time, communities, regions, and the Federal government came to recognize that publicly owned roads were critical to a robust economy, because publicly owned roads allowed anyone to deliver goods and services to companies and citizens (using the public roads).

In the 21st century, the roads are made of fiber. Some community-owned infrastructure will be necessary if all citizens and companies are to have a full and equitable opportunity to participate in the Information Economy. Can we imagine a situation in which all roads are privately owned, and in which we would pay road tolls to go to the grocery store or to the dry cleaner?

With respect to telecommunications, we have that situation today in most communities. All telecommunications cable is privately owned, and many communities are being told that they must wait years before the infrastructure is upgraded.

> *Communities without affordable, high bandwidth telecommunications infrastructure will not be able to participate in the Information Economy.*

Without an open telecommunications “road” structure, small, entrepreneurial start-up companies (where 90% of the job creation in the United States occurs) will not be able to compete on a level playing field with established transnational corporations that have enjoyed decades of protected monopoly status.

Fortunately, the dramatic and steady decreases in the cost of fiber cable and telecommunications equipment makes it possible for any community to begin deploying a publicly owned telecommunications infrastructure. It is neither necessary nor desirable to try to “wire” an entire community all at once. Community infrastructure projects should be designed to be small, easily financed and installed, and easy to expand incrementally as demand grows. It is very clear from experiences in Blacksburg and other communities where affordable broadband access is available that these projects can be easily managed and that they spur economic growth, particularly in high tech businesses.

In Abingdon, Virginia, a town of 7,000, BEV and Virginia Tech staff helped the town (http://www.eva.net/) install a modest downtown fiber backbone in 1997, it is now possible to get fiber Ethernet connections (10 millions bits per second) into any home or business in the downtown area. The county government (Abingdon is the county seat) cut telecommunications costs in half by physically moving some government offices into buildings on the fiber backbone, and the government was also able to give every single employee high bandwidth Internet access at their desks for the first time.

The town leases out fiber pairs to a local ISP that provides all customer services, maintains and buys all the equipment needed, and handles all billing. The ISP sends a check to the town each month for the leasing fees on the fiber pairs in use. With the exception of the “dark” fiber (dark fiber has not electronics attached to the ends of the fiber pairs to “light” it up), all the investment and all the jobs are in the private sector, where they belong. Not only does Net Access, the local ISP, pay the town for the use of the fiber pairs, but Net Access also pays taxes. This is an excellent example of a public/private partnership that works.

Components of a community-wide telecom infrastructure

There are several key components required to implement a community-wide telecommunications infrastructure. These components tend to be common across specific telecom services (i.e. components needed to provide telephone services are, at a certain level, functionally similar to the components needed to provide CATV (cable television) services). Figure 1 illustrates this idea.

❏ Basic infrastructure includes duct and wireless towers.

❏ Co-location facilities house network equipment needed to make the telecom systems work.

❏ Basic transport include cable plant and radio systems, including cable plant into the develop-

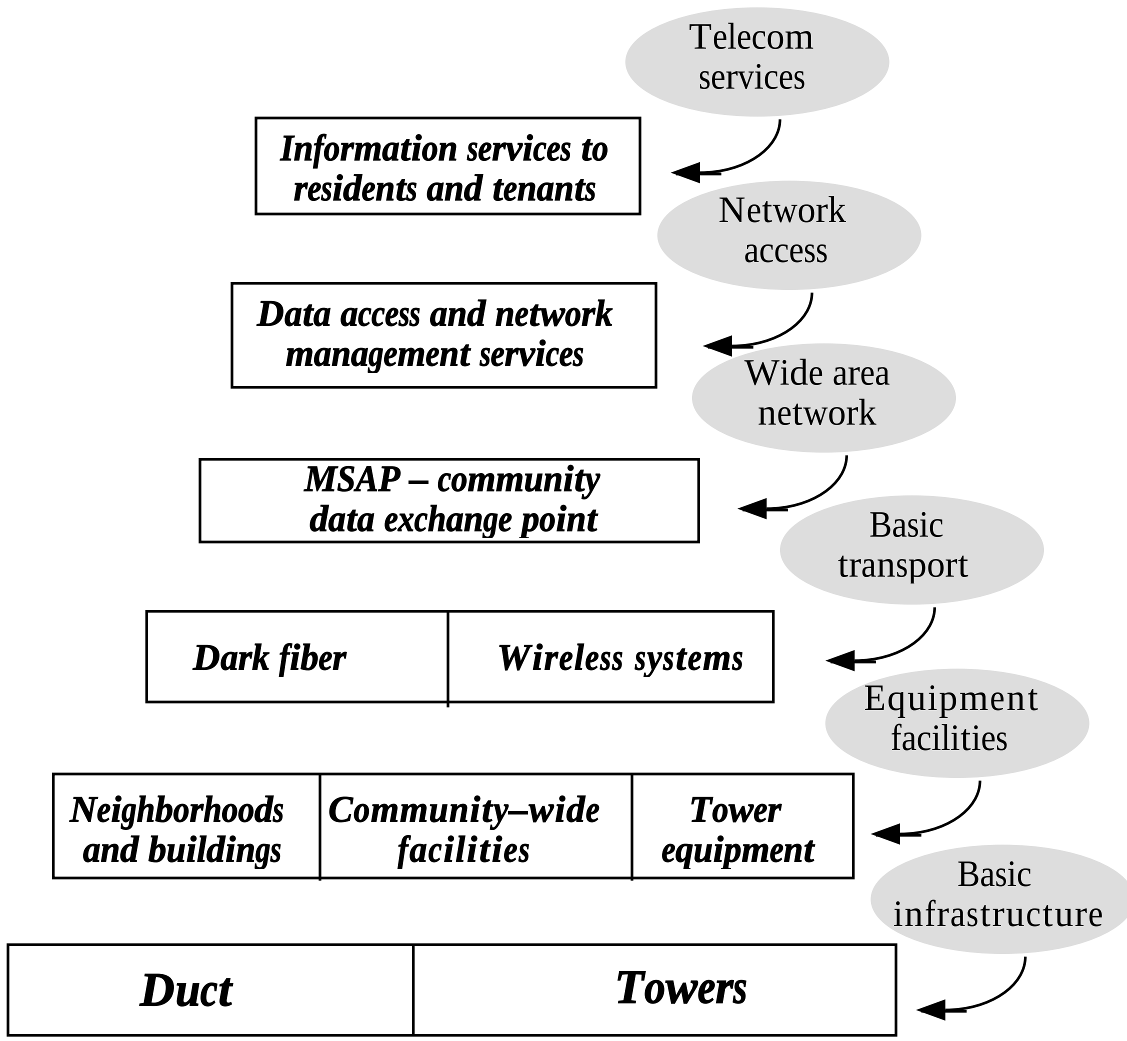

Figure 1: Hierarchy of community telecommunications sytems

ment, between major areas in the development (community-wide), and within neighborhoods and buildings.

- The Wide Area Network (or community-wide network) is created by one or more common data exchange points, located in co-location facilities. These facilities house the network equipment that provides access and services.

- Data access and network management is a mix of services and technical support needed to supply connections and services to end users.

- Delivery of new multimedia services using Internet technology will require implementation of new models for distribution that take into account all types of local infrastructure and offer support for evolving middle layer software components required for security, reliability, and application support.

This model must accommodate new infrastructure including fiber to the home, broadband wireless, wired multifamily dwellings and commercial properties, xDSL, cable modems, and others while leveraging to the greatest extent possible the ubiquity afforded by existing facilities. It must provide a mechanism to support economically scaled access and application services delivered to a community on efficient, very broad capacity links. And it must take into account a rational model for ownership and operation of its assets to promote the greatest possible community benefit while achieving sustainability and continued evolution.

The Multimedia Service Access Point (MSAP)

Figure 2 illustrates the "old" style of telecommunications services, in which each provider builds unnecessarily redundant facilities and provides end to end services without any consideration for exchanging data and services with competitors. This made sense in a regulated, monopoly telecommunications environment, in which only there was usually only one provider of each kind of service. It also made more sense before the Internet offered a way to carry multiple services (i.e. data, voice,

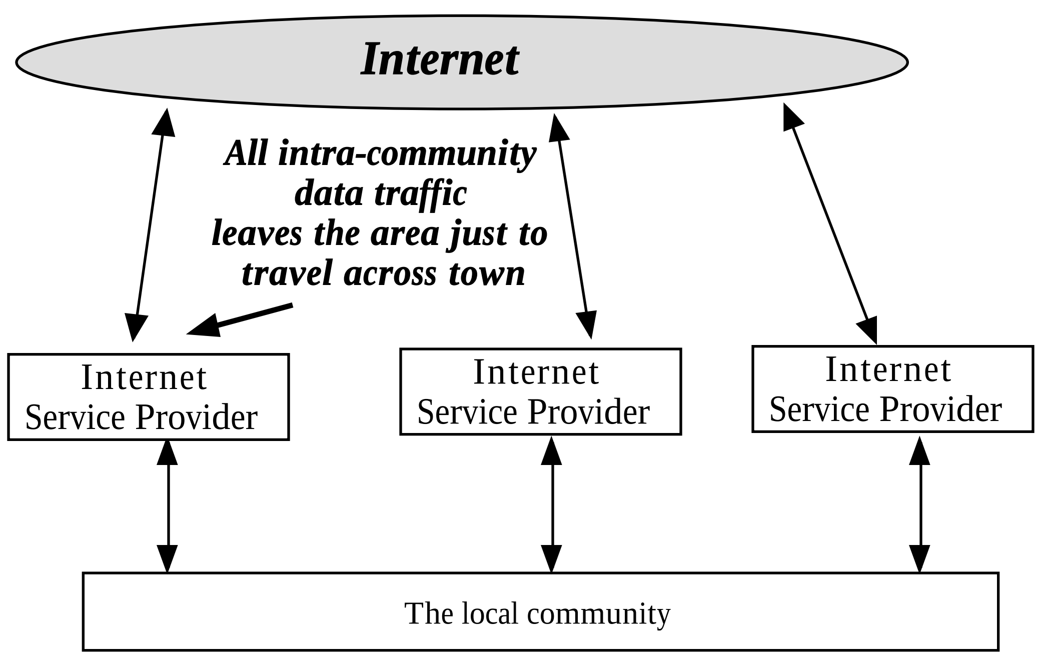

Figure 2: Obsolete Twentieth Century telecommunications infrastructure

and video) over a single cable and/or via a single service provider.

Figure 3 illustrates the "new" style of community telecommunications design, in which the community considers two key changes:

The deregulated telecommunications environment with multiple vendors in a community offering similar services, and
the fact that the Internet is creating convergence of services, whereby it is possible to provide mul-

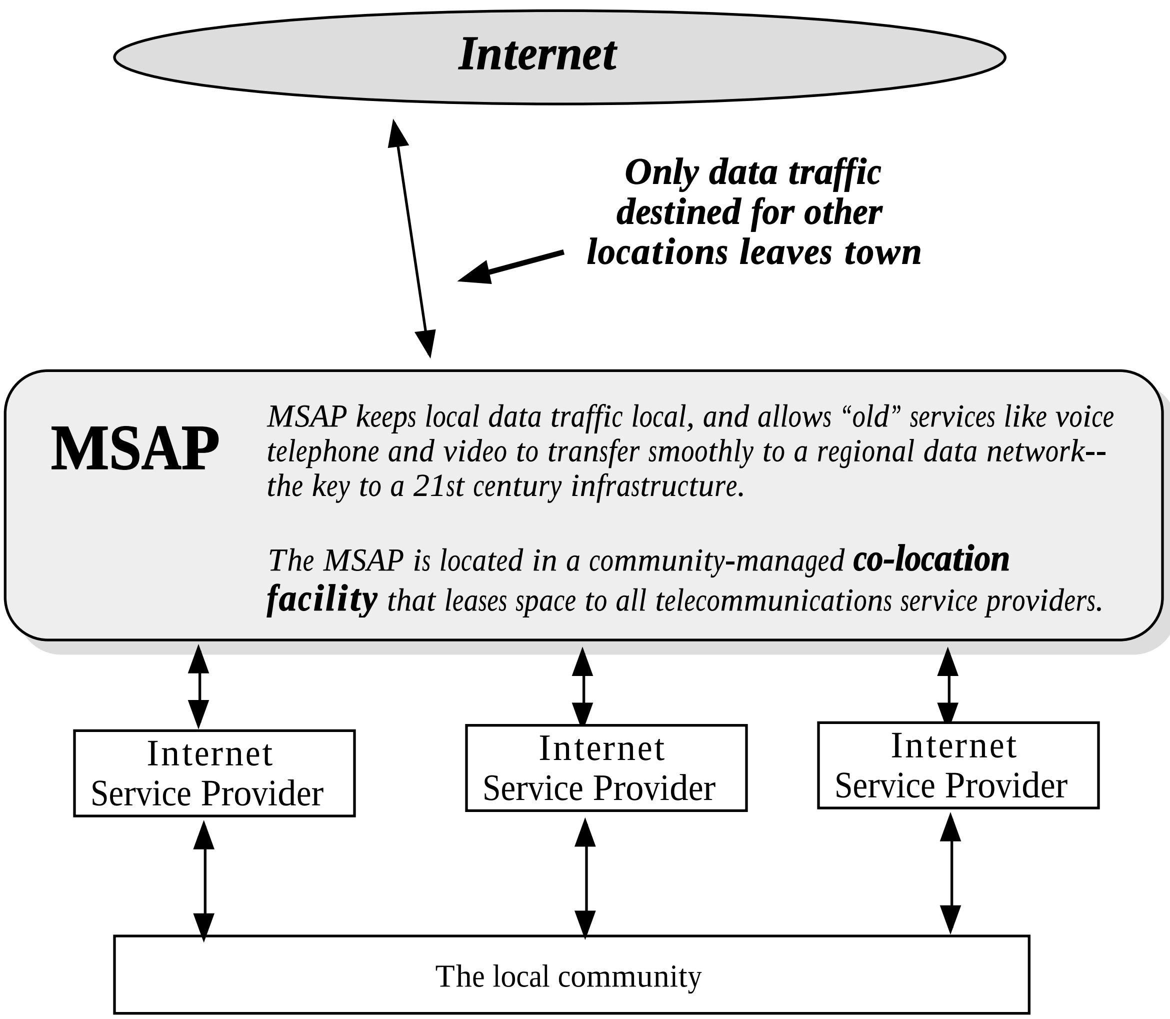

Figure 3: The twenty-first century community telecommunications architecture

tiple services from multiple vendors over a single cable.

Multimedia Service Access Points (MSAP) and co-location facilities are key components of a Next Generation Internet architecture enabling efficient, cost effective delivery of last mile services within communities.

- ❑ MSAPs will serve as community hubs that will provide exchange and access points.
- ❑ The MSAP will be a place where fiber, wireless, and copper-based network facilities meet.
- ❑ The MSAP will accommodate new economic models for ownership of last mile infrastructure. It will be equipped to house high-end network equipment, servers, and other electronic gear.
- ❑ Service providers and content providers of all types will have the opportunity to reach entire communities simply by extending their product to the MSAP. A variety of middle layer components can be located within the MSAP including, for example, directory services, replicated content servers, routing services, and other elements needed to deliver new multimedia services to the home and small office from multiple, competing providers.
- ❑ MSAPs will be deployed in a variety of ways designed to meet the specific requirements of the client community served. For example, an MSAP could be deployed within an information technology-enabled office park to provide service to tenants of the park. Or an MSAP might be deployed within a new planned residential community to deliver voice, data, and video services to the residents via a community owned, fiber optic network infrastructure.

Functions of MSAPs include:

- ❑ Hub for new broadband infrastructure development at the community and corporate campus level.
- ❑ Exchange point for local service providers to peer reducing costs and increasing performance in a win-win-win scenario (keep local traffic local).
- ❑ Insertion point for multimedia services from multiple competing providers to reach subscribers over single broadband medium (fiber, wireless, other).
- ❑ Community, campus, or building point of presence for new middle layer components required to implement next generation Internet (directory services, caching, routing).
- ❑ Focal point for technical resources and management of community infrastructure.
- ❑ Aggregation point for low cost access to gigabit scale network services.

The MSAP is the key infrastructure component

The starting point for a community-based telecommunications infrastructure can be an MSAP (Multimedia Services Access Point). The goal of an MSAP is to provide a central, broadband switching and network access point for all Internet, voice, and video traffic in a community. An MSAP has the potential to substantially reduce the traffic and cost of Internet feeds for all ISPs connected to the MSAP. Furthermore, the availability of a local broadband switch point can help spur the development of new local information services that require high bandwidth for short periods of time, like video on demand, multi-point gaming, and videoconferencing.

In Blacksburg, the MSAP has been developed by Virginia Tech as part of the BEV project. Because of the increasing traffic between the Virginia Tech (VT) campus network and local ISPs, Tech's participation became very important. Packet losses of more than 50% had already been seen between one local apartment complex and Virginia Tech servers. Local Internet users were not aware of the relatively inefficient network routing, and tended to blame Tech servers and other local servers as being "slow". Figure 4 illustrates a pre-MSAP routing path for a piece of email. Figure 5 on the next page shows how the MSAP creates a more efficient second route for local traffic.

As more apartments and businesses in town become wired, a MSAP became the only cost-effective solution to the problem of efficiently routing packets around Blacksburg. The unofficial slogan of the Blacksburg MSAP planners became, "Keep Blacksburg packets in Blacksburg!"

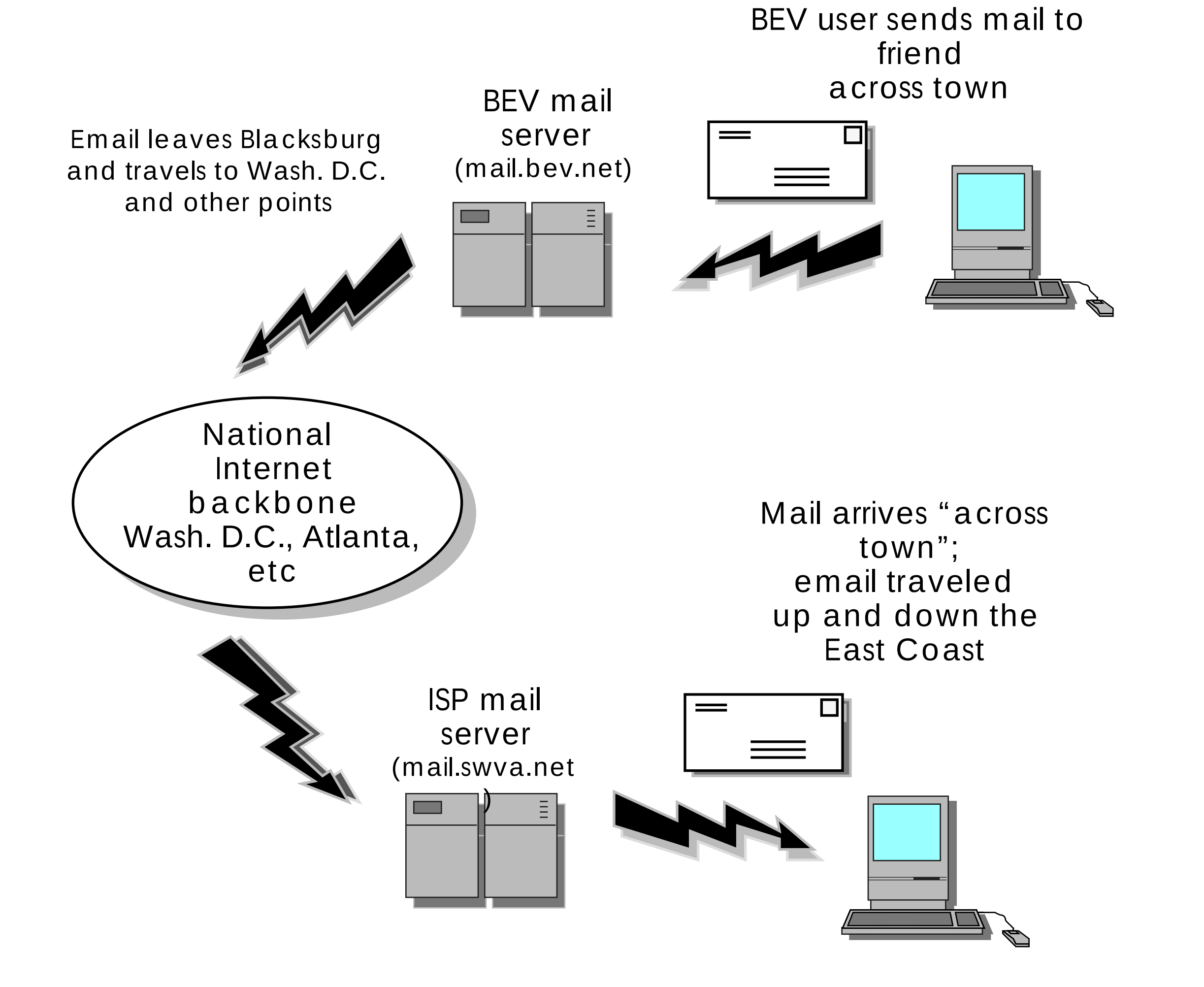

Figure 4: Blacksburg before the MSAP was activated

The creation of an MSAP also offers the possibility of disaggregating local information services from Internet access. Currently, the worldwide Internet is used as the switching point for local Blacksburg traffic. This creates enormous inefficiencies, and limits the development of innovative local information services because of the requirement to purchase an expensive Internet feed (currently about $2500/month). The creation of the MSAP allows small local business entrepreneurs to market new information services and network systems to local customers without incurring the cost of a backbone Internet feed.

Location of an MSAP must be done carefully to minimize the cost of circuits needed to connect local service providers (ISPs and others) from the service provider office to the MSAP. Downtown areas are often ideal because the availability of good telecommunications infrastructure. Furthermore, locating broadband access points in downtown areas can be an excellent way to revitalize Main

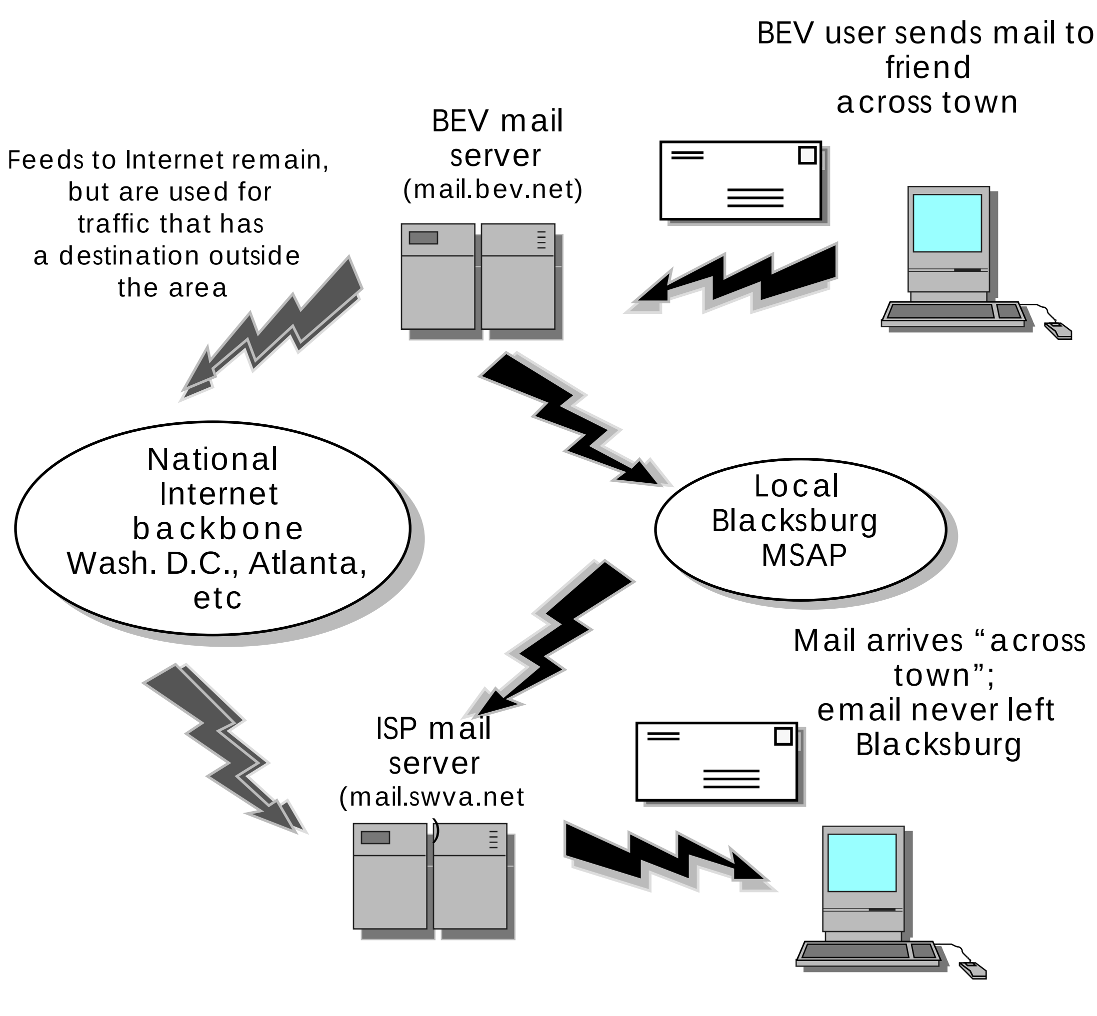

Figure 5: Blacksburg MSAP architecture

Street areas that have lost retail businesses to Wal-Mart style shopping on the edges of communities. The combination of an MSAP and low cost fiber connections can be a powerful economic development advantage, pulling white collar businesses and high tech enterprises in from other areas.

A recent BEV survey of local businesses indicated that some businesses would consider relocating into the downtown area if inexpensive, directly connected Internet access was available. This may be particularly attractive in small and medium-sized towns that have suffered as traditional retail businesses leave the downtown area.

Functions provided by the MSAP include:

- ❏ Basic IP routing
- ❏ A broadband switch point for public and private fiber in the community
- ❏ A broadband switchpoint for high bandwidth wireless services like LMDS
- ❏ A public directory server to help local users find and access online resources in the community, including individual users, businesses, Web sites, videoconference sites, and video on demand services.
- ❏ The MSAP can also host caching servers to speed access time for popular Internet services.
- ❏ The MSAP would have enough room to lease equipment space to service providers like videoconference services and video on demand services. Hosting these services at the MSAP can reduce costs for the service provider and reduce the cost of the service to consumers.
- ❏ The MSAP would have very high bandwidth connections to the national Internet backbone, which can reduce costs for local ISPs. A local ISP could purchase an Internet feed via the MSAP rather than paying for a leased line to a distant Internet connection point.
- ❏ The MSAP would also have a high bandwidth connection to the regional MNAP (Multimedia Network Access Point), which is the regional equivalent of the MSAP.

The combination of community MSAPs linked to a regional MNAP effectively creates a regional intranet where, in network terms, all services and users are equidistant in the network. This is desirable to spur economic development because it lowers costs for both service providers and service users (the equivalent of flat rate telephone use).

The MSAP in Blacksburg

In Blacksburg, a centrally located MSAP facility makes it economically feasible to connect many downtown municipal facilities, including the Lyric Theatre, the Thomas-Conner house, the Police Department, the Five Chimneys building, and the Town Hall. A preliminary engineering study conducted by the BEV for the Town showed that direct costs for a downtown fiber project (where the Town supplied labor) would be about $35,000. There are many other businesses in the downtown area that could also take advantage of a local MSAP/fiber project, which would provide better services to businesses and consumers while lowering the cost of service.

The Blacksburg MSAP project is managed on a cost recovery basis for all ongoing expenses incurred by Virginia Tech and the BEV. The current Blacksburg MSAP has eight T1 lines (fall, 2000) connected to it from various local and regional ISPs (Internet Service Providers). Service began in the spring of 1999, and the performance improvements were dramatic. For one ISP offering DSL (Digital Subscriber Line) service, packet latency time between a subscriber's home and the Virginia Tech campus dropped by an order of magnitude, from 500 milliseconds to 50 milliseconds. The number of router hops involved dropped from 16 to 4. In this case, the MSAP performed exactly as planned. The DSL traffic, just to traverse a distance of a couple of miles between two points in Blacksburg, was being switched through MAE-East (the central IP routing center for the eastern half of the United States). Users have reported dramatic improvements in responsiveness when accessing local Web sites and information services.

This is a two year pilot project to stimulate the development of private investment in high speed networks in the town. At the end of the two year trial (summer, 2001), the partners will review the status of the effort. It seems clear at this time that the MSAP, to be most effective and most useful to the entire community, should be operated on a nonprofit, cost recovery basis and should be managed by a disinterested third party rather than by a for-profit company. Any for-profit company managing a community MSAP would have a tremendous competitive advantage (just as local telephone companies have today with local central offices), and there will be little incentive for other telecommunications providers in the community to use MSAP facilities if the fees accrue to the advantage of a direct competitor.

The architecture of the MSAP

The generic MSAP facility (see Figure 6 on the next page) will typically be located in a community-managed co-location facility. The co-location facility will typically be an enclosed area of at least 500 square feet designed to meet applicable standards such as Telcordia (formerly Bellcore) Distribution Components specifications and Network Equipment-Building Standards (NEBS). The facility will be designed to consider aspects of mechanical and structural protection, including: power systems, floor plans, fire protection and HVAC systems, raised floors, suspended ceilings, cable racking, and environmental threats.
Key components include:

- ❏ Management -- management tools that allow remote monitoring and maintenance
- ❏ Security -- security and access control protocols for both services and physical equipment like servers, routers, and hubs
- ❏ Content -- local content may be provided, like directory services to help users find and access local resources like printers, email addresses, Web sites, fax services, etc.
- ❏ Cache -- caching servers may be installed to improve performance for certain services (i.e. a Web page caching system).

Wireless services like LMDS and MMDS must be switched onto and through wired systems. The

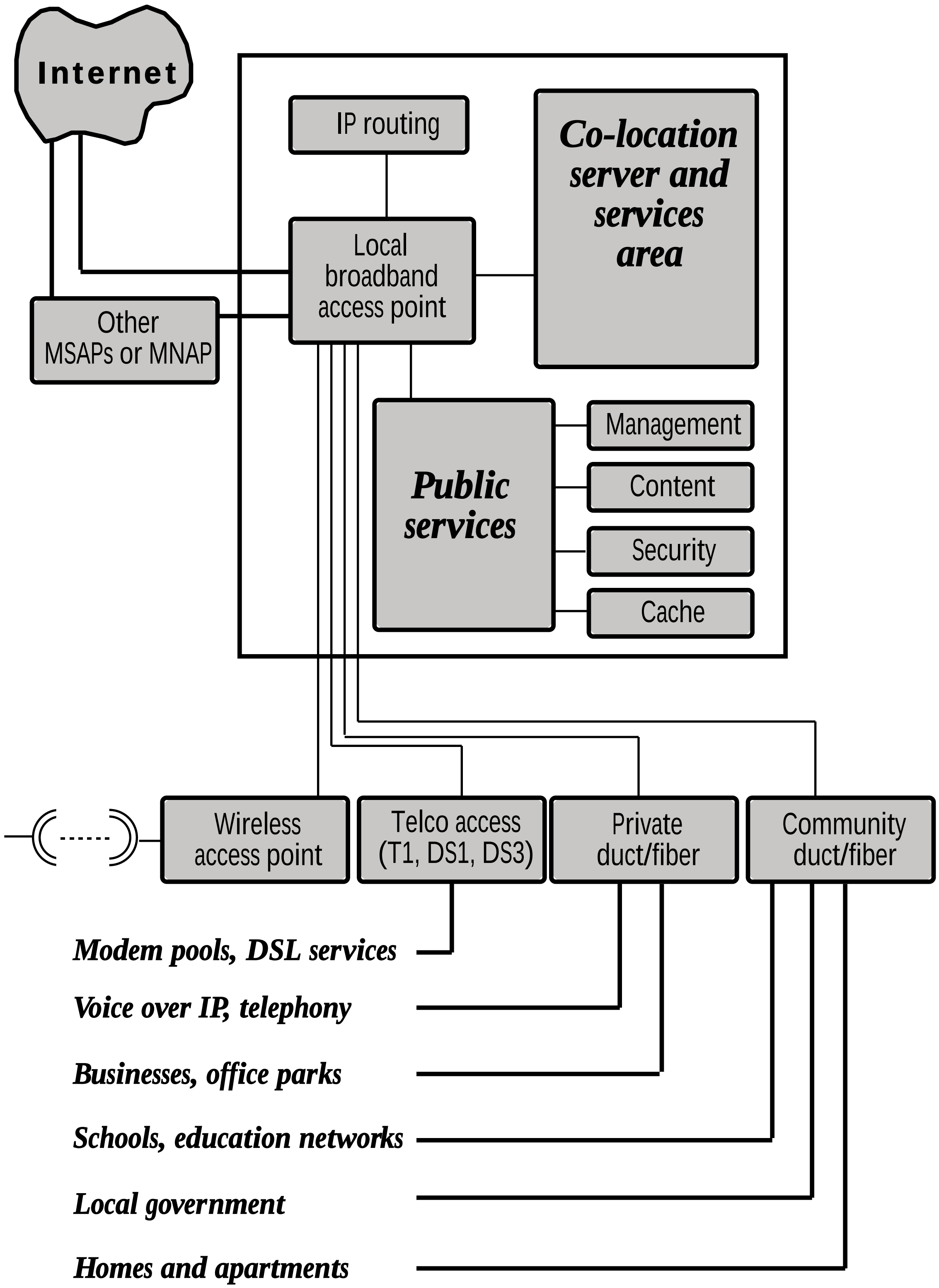

Figure 4: Architecture of a co-location and MSAP service facility

MSAP provides a convenient location for this.

Co-location space are available in the MSAP (typically industry standard 19" racks) for information service providers that want to reduce costs by gaining broadband access at a central location. These services might include videoconference system, streaming video, and video on demand services that would be impractical to offer economically without a central broadband aggregation point.

The network architecture within an MSAP will include multi-service switch facilities designed to enable communication among subscribers and delivery of service from application service providers. The switch environment could, for example, support peering between locally connected Internet Service Providers and content providers.

The MSAP will be designed to support a variety of plug in services. For example, service providers will be able to plug in voice, Internet, entertainment, or other products for delivery to subscribers. Operators of the MSAP will be able to plug in common service components such as IP routing, caching, or middle-ware such as directory services as required. Design for the MSAP will include ample additional rack and floor space and environmental support to accommodate these plug-ins. The network architecture should easily adapt to delivery of new types of services and scale to meet increasing performance requirements.

MSAPs will be strategically located taking into account proximity to end users, service providers, existing and prospective fiber facilities, rights of way, line-of-sight for wireless communications, cost, serviceability, and other factors. The objective will be to reach all potential service subscribers with maximum performance at minimum cost. Subscribers may connect directly to the MSAP using fiber, wireless, or other broadband media or may be connected by a local incumbent or competitive service provider.

MSAPs will be served by at least one broadband service provider offering at a minimum high performance Internet access. It is expected that MSAPs will typically offer voice services in addition to Internet service. Ideally, MSAPs will offer distribution for voice, entertainment, education and other services provided by multiple, competing application service providers. The intent is to provide a common interface and exchange point to enable very rapid development of multimedia services delivery at minimum cost. As appropriate, MSAPs may be connected to the Internet2 and Next Generation Internet national infrastructures.

Public infrastructure investment

Every community will have different geographic and infrastructure limitations; there will not be a "one size fits all" network configuration that will meet the needs of every community. It is likely that both "wired" and "wireless" solutions will have roles to play. With both approaches, though, there are some areas of investment that are very strong candidates for community-owned infrastructure development.

In a "wired" scenario, there are three key components that communities will need to manage on behalf of the public good. Note that these facilities and components need not necessarily be owned and managed directly by a local or regional government entity. A community-owned nonprofit may be a better entity, with local government having a significant equity stake and/or participating as a major customer for services.

Wired components

- Conduit and/or dark fiber is the first component of a community-owned telecommunications infrastructure. It is not cost effective to have multiple telecommunications companies all digging up community streets and neighborhoods piecemeal to install network upgrades. By designing a community overlay plan for conduit and/or dark fiber, and building out incrementally, communities could lease conduit and/or dark fiber on a first come-first serve basis to any public or private entity trying to develop a network.

- The second component of a community-owned telecommunications infrastructure is a colocation facility. This is simply a centrally located building or space where telecommunications providers can lease space for their network equipment and servers. This facility is placed to make it easy to connect to the fiber/duct system.

- The third and final component of this community infrastructure system is the most important. With multiple telecommunications providers in a community, there is a need for a common data exchange point where all community data (public and private), can be moved from one local network to another. This facility has to be managed on a nonprofit basis with equal access to all users. The MSAP is described in more detail later in this document.

Wireless components

The design of a wireless community infrastructure follows a similar pattern.

- The first component of a community wireless system actually has two parts: the spectrum to be used, and a system of community antennas. The spectrum (or frequency range) of the wireless system (there are several different spectrums that can be used) will determine where antennas will be located. Antenna locations are a scarce resource that must be managed on behalf of the community to avoid redundant antenna systems (which can cause interference problems) and to minimize the negative visual effect antennas may have on skylines and the community. Towns investing in community-owned antenna system can require telecommunications companies to use community antennas, much as towns currently regulate rights of way for wired systems.

- Colocation facilities are also needed in wireless systems. Not only is a central colocation facility needed, but a colocation building or hut is needed at the base of every antenna, which will be used by the companies leasing antenna space. The buildings will house the wireless electronics needed to energize the wireless system (just as electronic equipment is needed to light up dark fiber).

- Finally, an MSAP is still needed to provide a common place to exchange local data packets, whether they are carried on a wireless system or over dark fiber.

Cost/fee scenario for a MSAP user

Fees paid by a MSAP user will vary according to type of service. Listed below are several connection scenarios that reflect "typical" customer needs.

An customer in the downtown area that is near the town fiber backbone would pay for:

-- basic service connection to the MSAP
--fiber pair lease to get from the ISP building to the MSAP building
--a fiber connection could a 10 megabit (Ethernet) , 100 megabit (Fast Ethernet), or 1000 megabit (Gigabit Ethernet)
--interconnect agreements with other MSAP users

A customer with low bandwidth needs would probably choose to use frame relay:

--basic service connection to the MSAP
--MSAP frame relay connection service fee
--frame relay circuit costs into the telco frame relay cloud
--interconnect agreements with other MSAP users

An customer with high bandwidth needs would require:

--basic service connection to the MSAP
--T1 circuits from customer location to the MSAP
--interconnect agreements with other MSAP users

An customer interested in co-locating equipment in the MSAP would pay for:

--basic service connection to the MSAP
--MSAP colocation fee based on floor space/rack space needed
--interconnect agreements with other MSAP users

Architecture components of a MSAP

❑ Central location in the community often helps downtown revitalization efforts.

❑ Fiber circuits between MSAP and telephone company CO must be available.

❑ Sufficient space for a rack of equipment to implement the MSAP.

❑ Additional space is desirable for colocation opportunities for local ISPs.

❑ Downtown location is desirable to facilitate development of fiber networks in local commercial office space.

The initial architecture of the MSAP can consist of a simple 10 Mbit/s Ethernet backbone, collapsed into a fiber concentrator. As customer demand increases, the architecture can include a high capacity ATM switch. The ATM switch will allow traditional T1 and frame relay circuits to be connected to the MSAP, and provide the switching capacity to connect, switch, and/or route higher bandwidth connections like Fast Ethernet, Gigabit Ethernet, DS3 (45 megabits/second), OC3 (155 megabits/second), and OC12 (655 megabits/second) connections. These higher speed connections are necessary to provide efficient switching and routing of voice and video circuits.

Sample startup plan

Rent and utilities represent an ongoing cost. It is necessary to identify an independent third party (community network or non-profit corporation) to guarantee all rent, utilities, phone line for out of band monitoring, and miscellaneous services related to providing the physical space for the MSAP (for this discussion, we will call it 'MSAPC0'). The MSAP switch room should be at least 12' x 12' square and have adequate electrical power and heating/cooling to support several racks of electronic equipment (future expansion). This cost is estimated to be approximately $350/month, including utilities.

MSAPCO would be responsible for installing fiber cable, duct, and pedestals as needed to extend network services to and from the MSAP. MSAPCO would lease out use of fiber pairs to all interested parties, public and private, on a first come, first serve basis.

MSAPCO would provide all miscellaneous equipment needed to furnish the MSAP (equipment rack, surge protectors, power cords, modem for out of band monitoring, etc). Estimated cost is $1800.

MSAPCO would purchase (used equipment might be appropriate for a start up service) a fiber concentrator and related equipment for service connections in the MSAP during the two year pilot phase. There are many equipment options available, and it is beyond the scope of this paper to discuss them, but the equipment needed to provision an MSAP may range between a low of about $20,000 for a very low cost service using a collapsed Ethernet to $100,000 or more if multiport routers and/or ATM switching is needed.

Ongoing management and fees

There will be an initial connection fee to cover the costs of installing customer connections to the MSAP.

Each MSAP customer will pay a monthly connection fee to cover all out of pocket expenses incurred by MSAPCO.

Each MSAP customer will cover the initial and ongoing costs of providing their circuit connection to the MSAP (i.e. T1 circuit, leased fiber pairs from MSAPCO, etc).

Customers will have several service options for connecting to the MSAP.

1. Direct 10BaseFL connection. Customers that lease fiber pairs from the local fiber utility, or who equipment located nearby may provide a 10BaseFL port for direct connection to the MSAP concentrator. This connection will be serviced at the base price.

2. A "full-service" WAN port. In this option, the MSAP provides the router port, CSU, etc, and manages one end of the connection. The cost of the equipment, long-term maintenance, and HR costs for management of the equipment are factored into the port fee charged to the customer.

3. A co-location agreement option. Customer locates in the MSAP facility all equipment necessary to deliver a 10BaseFL port to the MSAP concentrator. The co-location agreement specifies terms and conditions including, but not limited to, liability for loss or damage, timely access for service requirements, required out-of-band access facilities, etc. It will be necessary to factor into the fee such factors as power and HVAC requirements, long-term space considerations, etc, as well as the (marginal) cost of keeping someone on-call to provide physical access to the facility.

4. Customers not able to obtain a fiber feed to the MSAP immediately could purchase a frame relay connection to the MSAP. The MSAP could support numerous connections at a 256Kbps committed information rate (CIR) by using two T1 leased lines into the local telco frame relay cloud.

Each MSAP customer will independently negotiate routing agreements with other MSAP customers as needed. Connection to the MSAP and the MSAP service fee provides only for connection to a common packet switching point.

Once the MSAP is operational, additional services might be provided by MSAPCO, including special connections and circuits as new technologies become affordable, like xDSL and ATM. Because ATM can carry voice, video, and data simultaneously, a MSAP with ATM switching capabilities would provide the base infrastructure to enable very high quality videoconference capabilities in the community–between schools, between government offices, and between business offices. Transport costs would be relatively low because all data remains in the local area community network. Local video on demand services would also become economically feasible, creating new competition and alternatives to traditional cable systems.

If a major backbone Internet provider could be brought in to the MSAP, all public and private Internet feeds could be serviced from the MSAP rather from remote POPs (Points of Presence), resulting in dramatic reductions in the cost of Internet connectivity for local users.

If a local phone company or CLEC (Competitive Local Exchange Company) installed a voice switch in the MSAP, voice over IP switching capabilities could offer new alternatives to traditional circuit-based voice telephone systems.