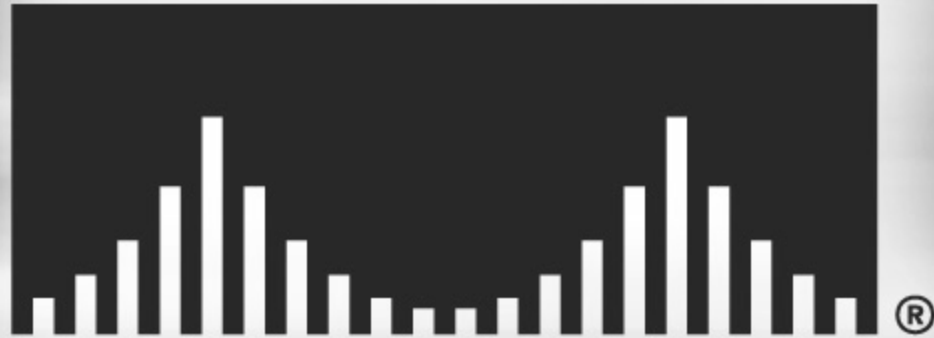# CISCO SYSTEMS

Cable-Based Network Solutions

Patrick Toal

Systems Engineer

Cisco Systems

Cable-Based Network Solutions

Agenda

- **Introduction to Cable Networks**

- **Cable Modem Technology**

- **Services**

- **Q&A**

Introduction to Cable Networks

- ## Introduction to Cable Networks

  ### The Electomagnetic Spectrum

  ### Cable Network Architecture

  ### Fibre-Optic Technology

- ## Cable Modem Technology

- ## Services

- ## Q&A

The Electromagnetic Spectrum

Waves

Almost all digital communication methods work by the manipulation of "Waves"

A ripple in a pond is a wave in water

An RF carrier is a wave in electrons

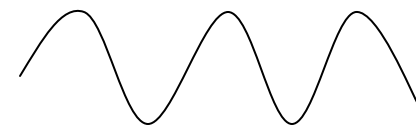A beam of light is a wave in photons

The Electromagnetic Spectrum

Frequency

- **The number of wave crests that occur in a time period**
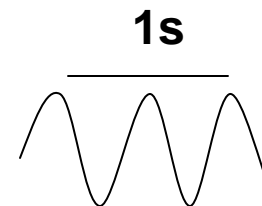
- **Cycles per second = Hertz (Hz)**

  1,000 Hz = 1 kHz

  1,000,000 Hz = 1 MHz

  1,000,000,000 Hz = 1 GHz

1 cycle / second = 1Hz

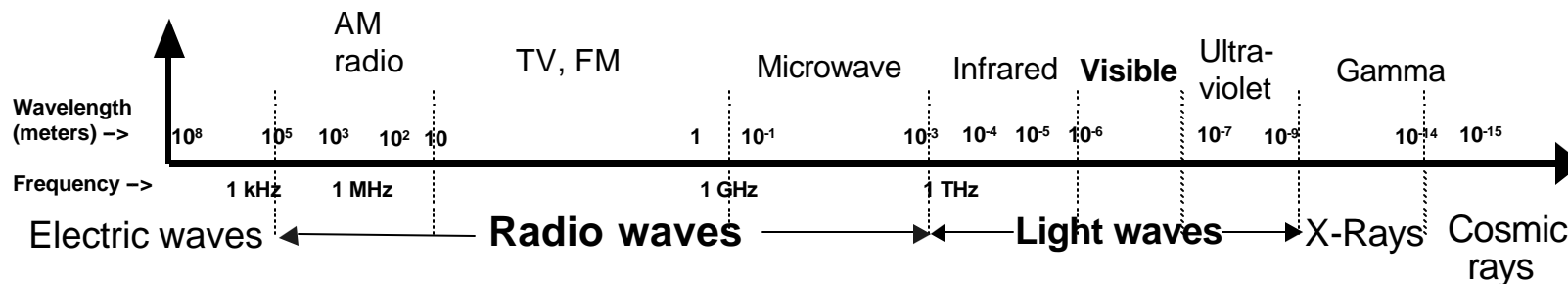1s

2 cycles / second = 2Hz

The Electromagnetic Spectrum

Common Frequencies

- **Musical Note A above middle C = 440 Hz**

- **AM 680 Radio =~ 680 kHz (680,000 Hz)**

- **FM 102.1 Radio =~ 102.1 MHz (102,100,000 Hz)**

- **Microwave Oven =~ 2.5GHz (2,500,000,000 Hz)**

- **Visible Red Light =~ 4.6×10^{14} Hz**

- **X-Ray =~ 3×10^{19}**

The Electromagnetic Spectrum

AM radio   TV, FM   Microwave   Infrared   **Visible**   Ultra-violet   Gamma

Wavelength (meters) –> 10^8 10^5 10^3 10^2 10 1 10^{-1} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-9} 10^{-14} 10^{-15}

Frequency –>   1 kHz   1 MHz   1 GHz   1 THz

Electric waves   ←—— **Radio waves** ——→   ←— **Light waves** —→ X-Rays   Cosmic rays

• RF (radio frequency):

Generally considered to be electromagnetic energy from a few hundred kilohertz to just below infrared light

The Electromagnetic Spectrum

RF Bandwidth

- **RF Bandwidth refers to the <u>width</u> of the frequency <u>band</u> used.**

- **RF Bandwidth does <u>not</u> always translate into Bit Rate**

    The bandwidth used by an analog telephone line is ~3000 Hz

    The bandwidth used by an FM radio station is ~200 kHz

    The bandwidth used by a Television Channel is ~6 mHz

Cable-Based Network Solutions

Television Channels

- **Each North American television station uses a 6 MHz wide carrier.**

- **Each of these signals is modulated to an allocated frequency on the cable network.**

- **These frequencies are 'tuned' to when you select a channel on your television.**

RF Channel Lineup

1 MHz — 54 MHz — 88 MHz — 108 MHz — 174 MHz — 216 MHz

Over-the-air	Shortwave	Land mobile & paging	Ham	TV Ch. 2-4	TV Ch. 5-6	FM	Aircraft navigation & communication	Space re-searh	Ham	Land mobile	Gov't fixed, mobile	TV Ch. 7-13

Cable	T7	T8	T9	T10	T11	T12	T13	2	3	4	5	6	95	96	97	98	99	14	15	16	17	18	19	20	21	22	7	8	9	10	11	12	13

5-42 MHz upstream

216 MHz — 432 MHz

Over-the-air	Ham	Gov't fixed, mobile, & aeronautical	Harbor navigation & Coast Guard	Gov't fixed & mobile	Ham

Cable	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58

432 MHz — 470 MHz — 648 MHz

Over-the-air	Ham	Land mobile	UHF TV Ch. 14-69

Cable	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94

648 MHz — 806 MHz — 864 MHz

Over-the-air	UHF TV Ch. 14-69	Cellular, public mobile, private base, public base

Cable	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135

864 MHz — 902 MHz — 928 MHz — 1002 MHz

Over-the-air	Cellular, etc.	Radiolocation, ham	Land mobile	Private fixed	Aircraft radionavigation

| Cable	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158

Cable Network Architecture

Symmetry

- **Cable Networks are asymmetric.**

- **The available frequency range is un-equally split between "Downstream" (to the subscriber), and "Upstream"**

- **Frequencies from 54MHz to 850Mhz are used for downstream information. (~125 TV Channels)**

- **Frequencies from 5MHz to 45Mhz are used for upstream information. (Equiv. ~5 TV Channels)**
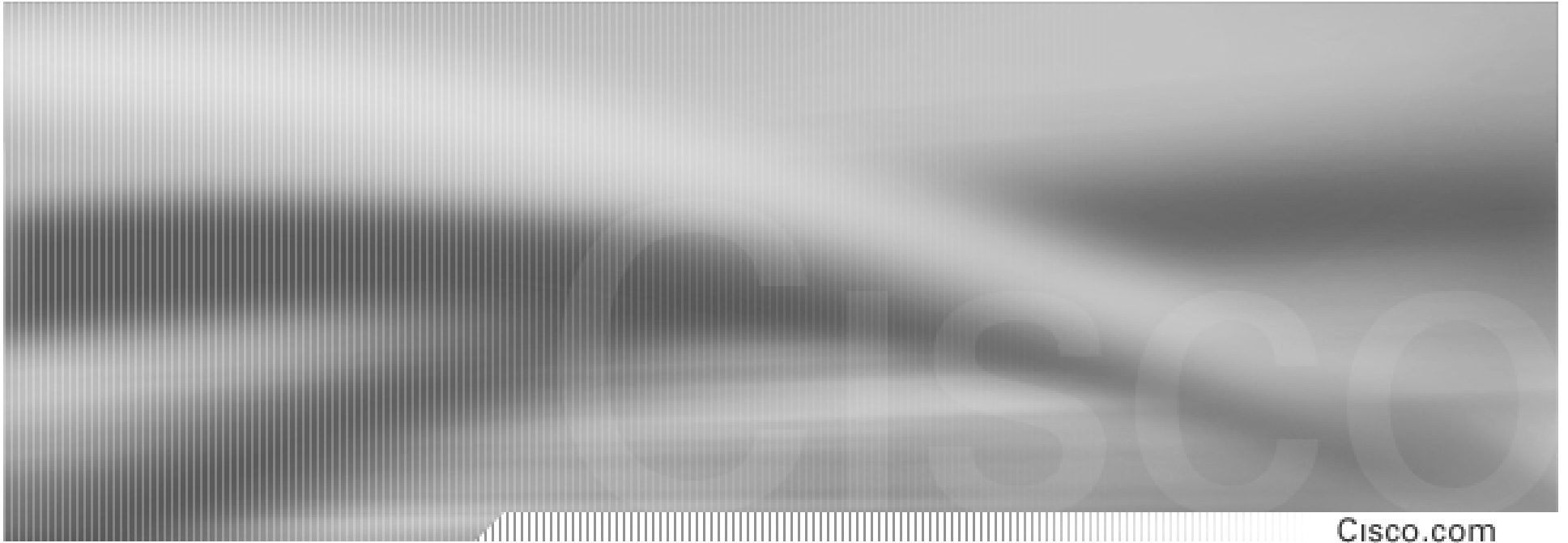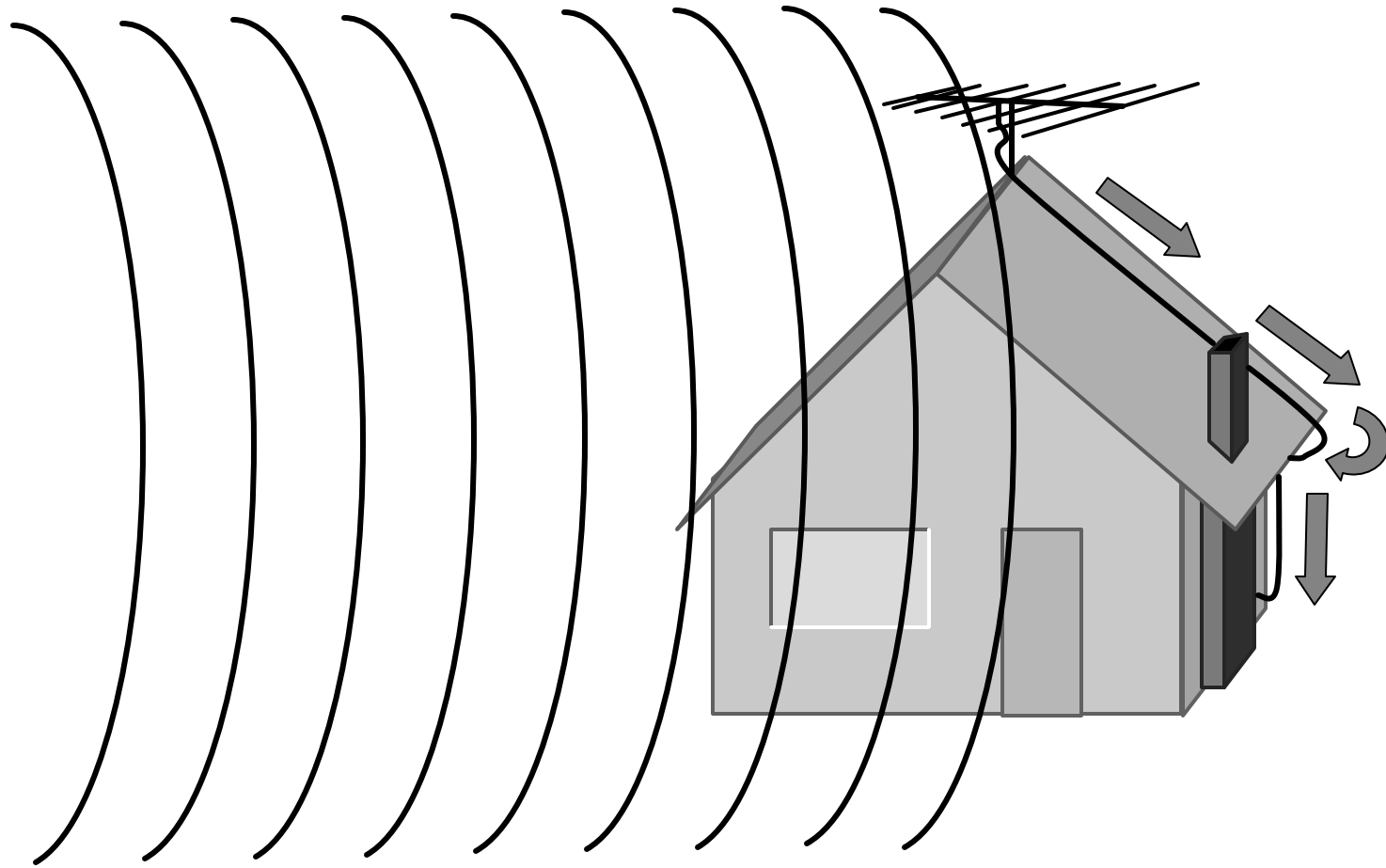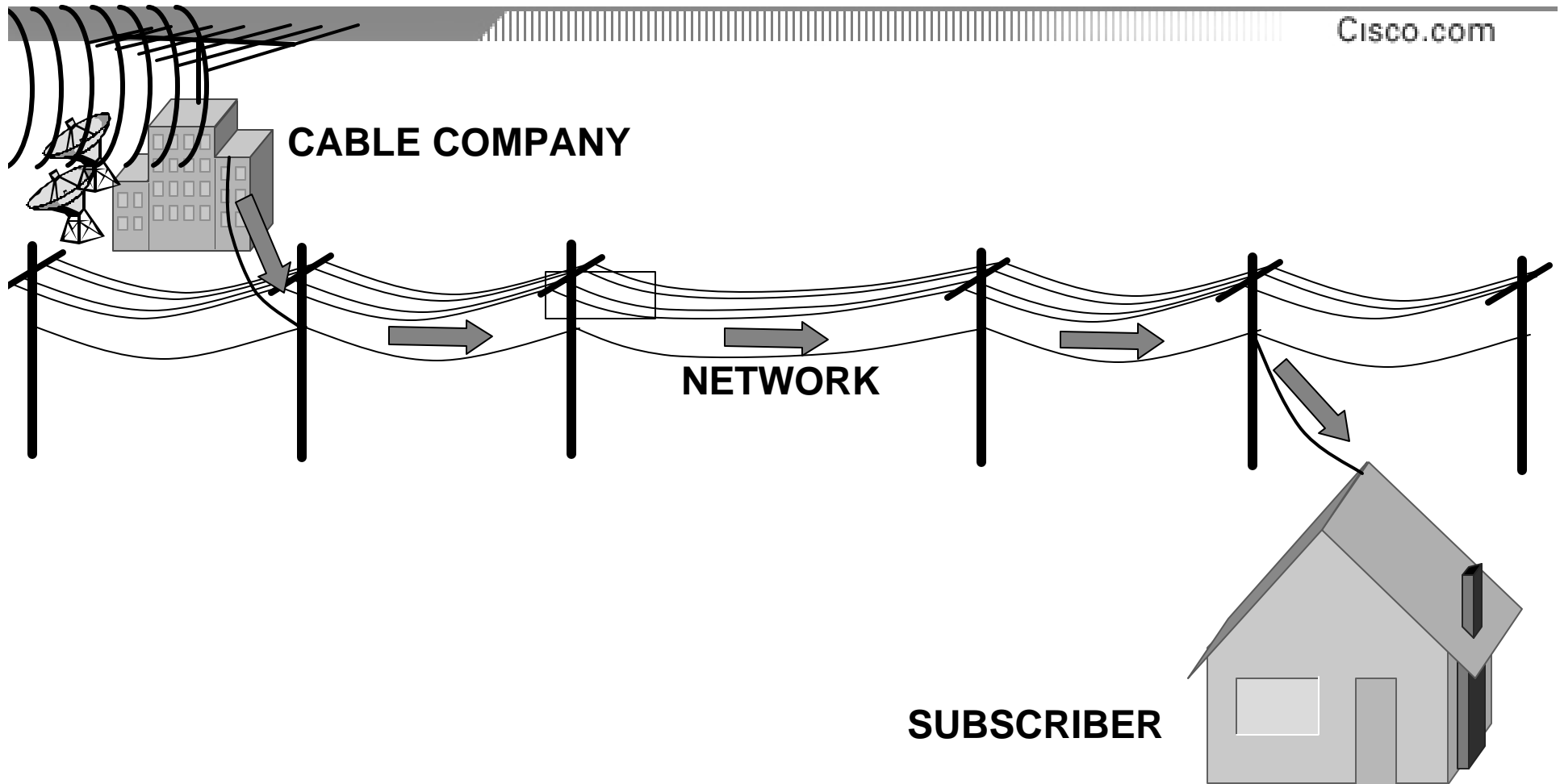
Cisco.com

Cable Network Architecture

Cable Network Architecture

Cable Network Architecture

CABLE COMPANY

NETWORK

SUBSCRIBER

Cable Network Architecture

- **Major components of a typical cable network:**

    Antenna site

    Transportation network

    Headend

    Distribution network

    Subscriber drop

Cable Network Architecture

- ## Antenna site:

  Exactly what its name implies: A location chosen for optimum reception of over-the-air signals, and sometimes also satellite and point-to-point microwave signals.

Cable Network Architecture

Cable Network Architecture

- ## Transportation network:

  Used where necessary to link a remote antenna site to a headend, or a remote headend to the distribution network. May be microwave, fiber, or coaxial supertrunk.

Here's a microwave link that's used to transport TV signals...

Cable Network Architecture

- ## Headend:

    Somewhat analogous to a telephone company's central office. A facility where signals are received, processed, formatted, and combined for transmission on the distribution network.

And here's what a headend looks like...

Cable Network Architecture

- ## Distribution network:

  In a classic tree-and-branch cable system, trunk and feeder cables comprise the distribution network.

  The trunk is the backbone; it distributes signals throughout the community being served. Typically uses 0.750 inch (19 mm) diameter coaxial cable.

  The feeder branches off of the trunk, and passes all of the homes in the service area. Typically uses 0.500 inch (13 mm) diameter coaxial cable.

# Cable Network Architecture

- ## Distribution network:

  In a hybrid fiber/coax (HFC) architecture, optical fiber replaces some or all of the traditional trunk portion of the distribution network.

  The network is divided into small service areas, each with from as few as 100 to as many as 2,000 homes passed. Fiber connects between the headend (or hub) and an optical node, where light is converted to RF. From the node, RF signals are distributed throughout the serving area via coaxial cable.

Distribution network

**Trunk/bridger amplifier;
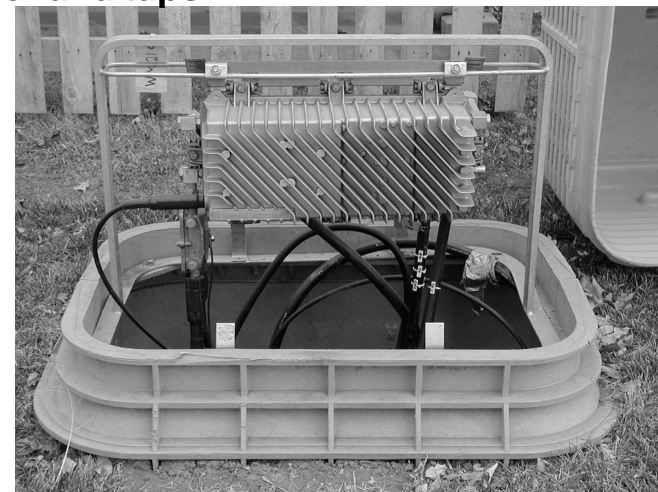directional coupler and splitter;
tap**
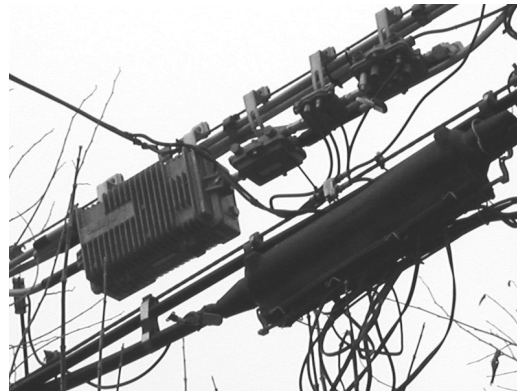
**Line extender amplifier,
directional coupler and taps**

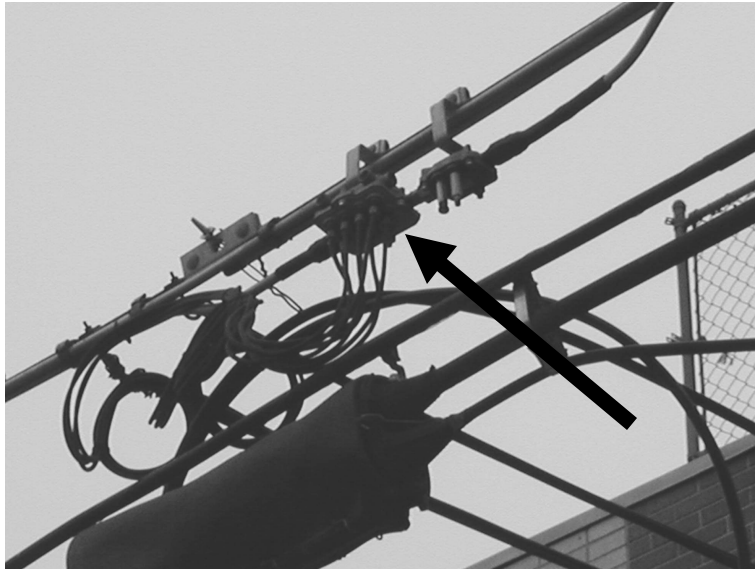**Standby (battery backup)
line power supply**

Underground pedestal

Optical fiber node

Subscriber drop from tap to TV set

Subscriber drops connected to feeder tap
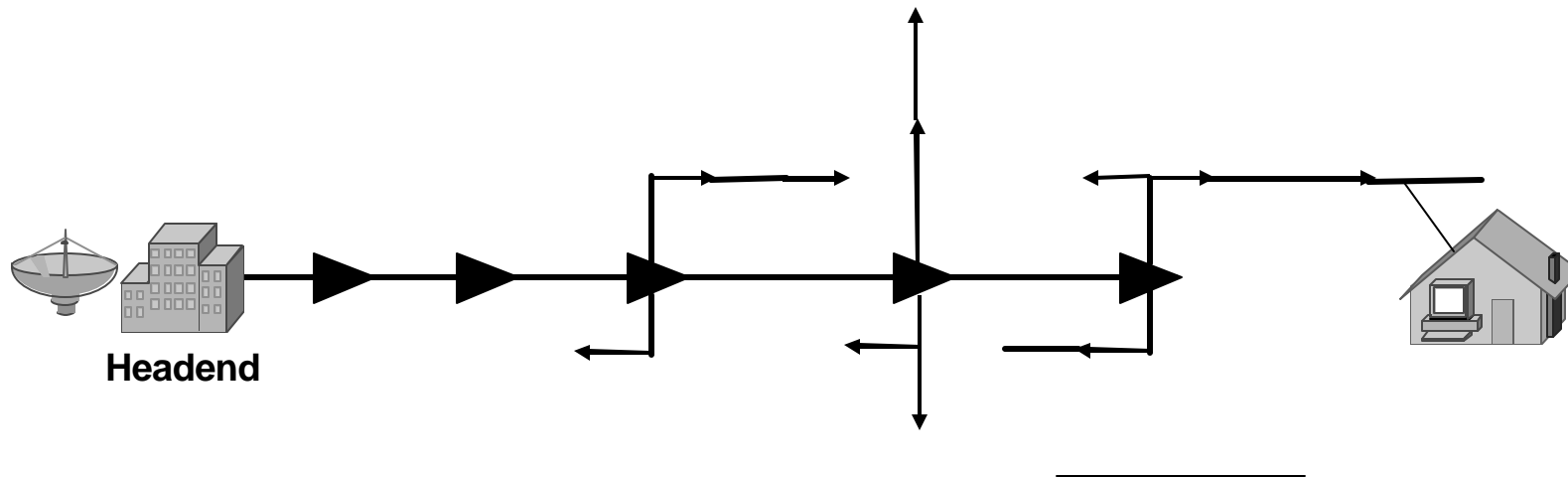
Set top box on top of subscriber's TV set
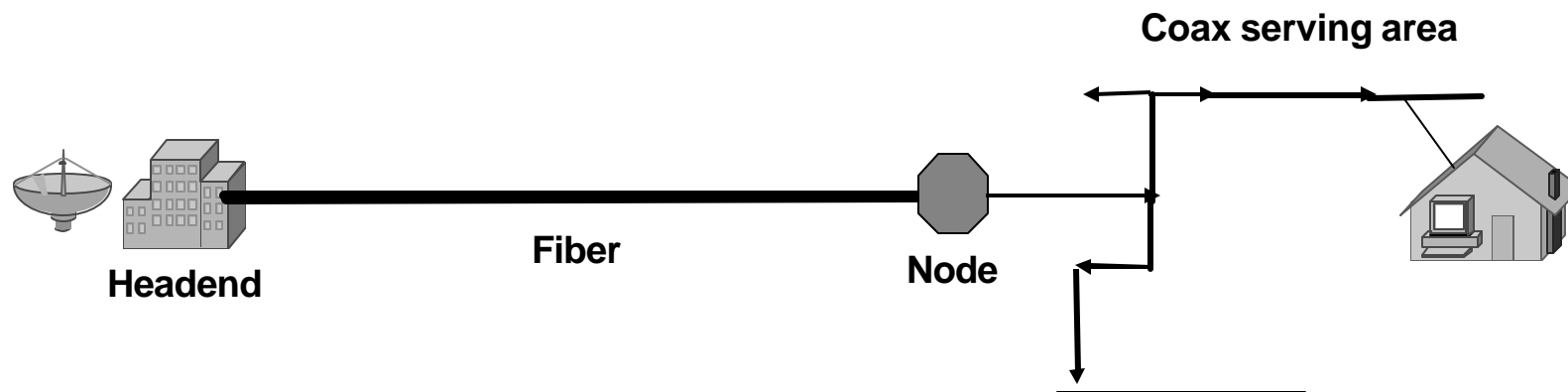
Cable Network Architecture

- ## Tree-and-branch

- ## Hybrid fiber/coax

  ### Fiber backbone

  ### Cable area network

  ### Super distribution

  ### Fiber-to-the-feeder

  ### Ring

Tree-and-branch architecture

Headend

- **Cost-effective "broadcast" architecture**
- **Con: Cascaded devices**

HFC architecture

Coax serving area

Headend

Fiber

Node

- **Segments network into smaller serving areas**

- **Use of fiber minimizes cascaded devices**

- **Improved quality and reliability**

- **Reduced operating costs**

Cable Modem Technology

Agenda

- **Introduction to Cable Networks**

- **Cable Modem Technology**

    Overview of DOCSIS

    Network Topology

    Security

- **Services**

- **Q&A**

Overview of DOCSIS

Downstream Data

- **DOCSIS uses a downstream channel to transmit data from the headend to subscribers.**

- **Each channel is capable of transmitting up to 38 Megabits/s to the users in a serving area.**

- **Typical areas have between 200 - 1000 subscribers per downstream.**

Overview of DOCSIS

Upstream Data

- **DOCSIS uses an upstream channel for traffic from the customer to the headend. There are 4 upstream channels per downstream channel.**

- **Each upstream can receive up to 10Mbps of traffic from subscribers.**

- **Each upstream typically serves 200 cable-modem subscribers**

Small cable system topology
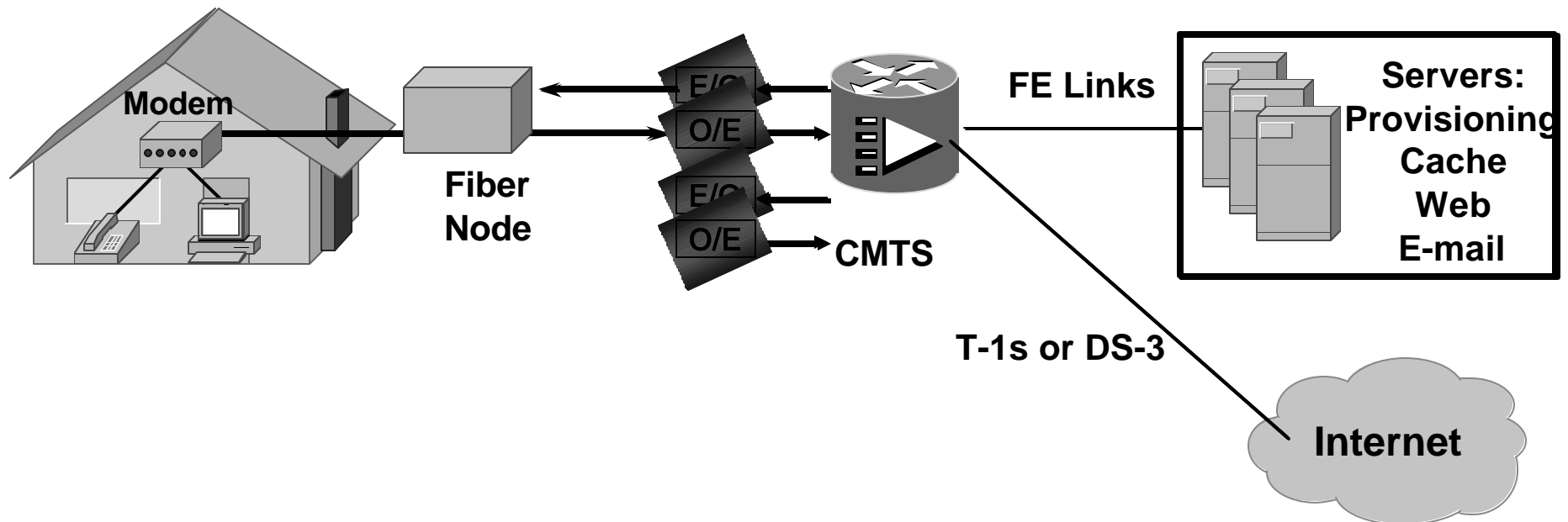
- Single box Cable Modem Termination System (CMTS) / Router

- The CMTS is responsible for coordinating timing and security for all cable modems connected to it.

Large cable system topology

Modem

Fiber Node

E/O

O/E

E/O

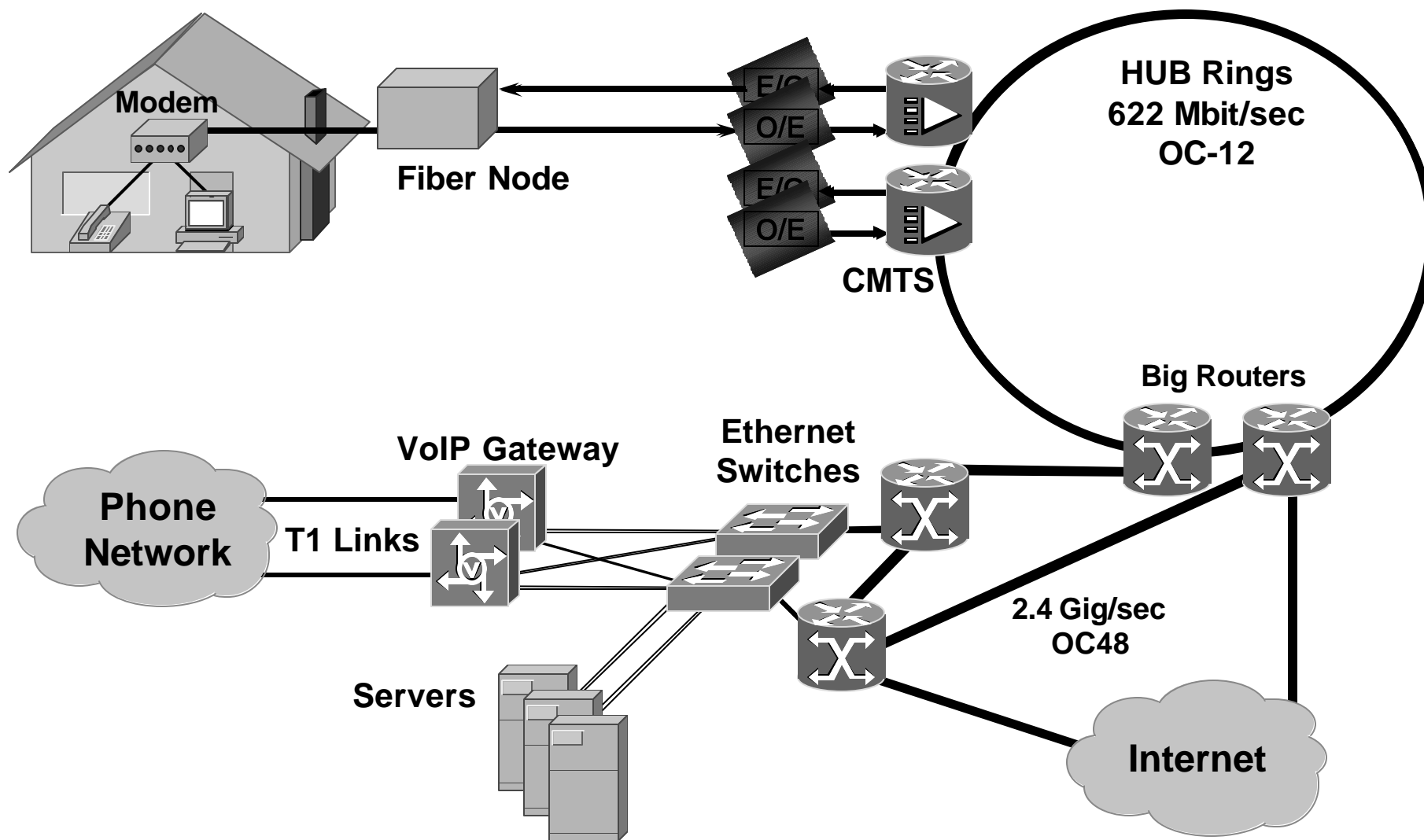O/E

CMTS

**HUB Rings
622 Mbit/sec
OC-12**

Big Routers

VoIP Gateway

**Ethernet
Switches**

**Phone
Network**

T1 Links

Servers

**2.4 Gig/sec
OC48**

Internet

DOCSIS Security

Baseline Privacy Interface Plus

- **BPI+ is a part of the DOCSIS spec. which addresses security in DOCSIS 1.1 networks**

- **BPI+ includes certificate-based authentication, and 168-bit 3DES encryption for data, and voice.**

- **Traffic between subscriber and cable operator is encrypted from the home to the head-end.**

- **BPI+ encryption happens at L2, and does not interfere with IPsec encryption.**

DOCSIS QoS

The "Shared" network that isn't

- **DOCSIS implements a robust scheduling mechanism that allows the CMTS to control who gets access to the network, and how much.**

- **Cable Modems must ask for bandwidth on the network before they are allowed to transmit.**

- **QoS can be implemented down to an application-level.**

- **Both priority-based, and guaranteed bandwidth allocation are possible.**

DOCSIS QoS

Voice over Cable

- **Voice is among the most demanding applications for latency, and jitter.**

- **DOCSIS 1.1 is designed to be able to transport voice within the strict delay requirements.**

Services

Agenda

- **Introduction to Cable Networks**

- **Cable Modem Technology**

- **Services**

    Internet

    VPN

    Future

- **Q&A**

Enterprise Productivity Challenges

Corp Office Toronto
416-555-1212

Toronto

Internet

PSTN

I'm working from home today, call me at
416-444-5678

I'll be in Montreal Today. Call me at
514-847-1234

Can I use the Phone now?

Home Office

Vancouver

Calgary

Montreal

Off-Campus Productivity
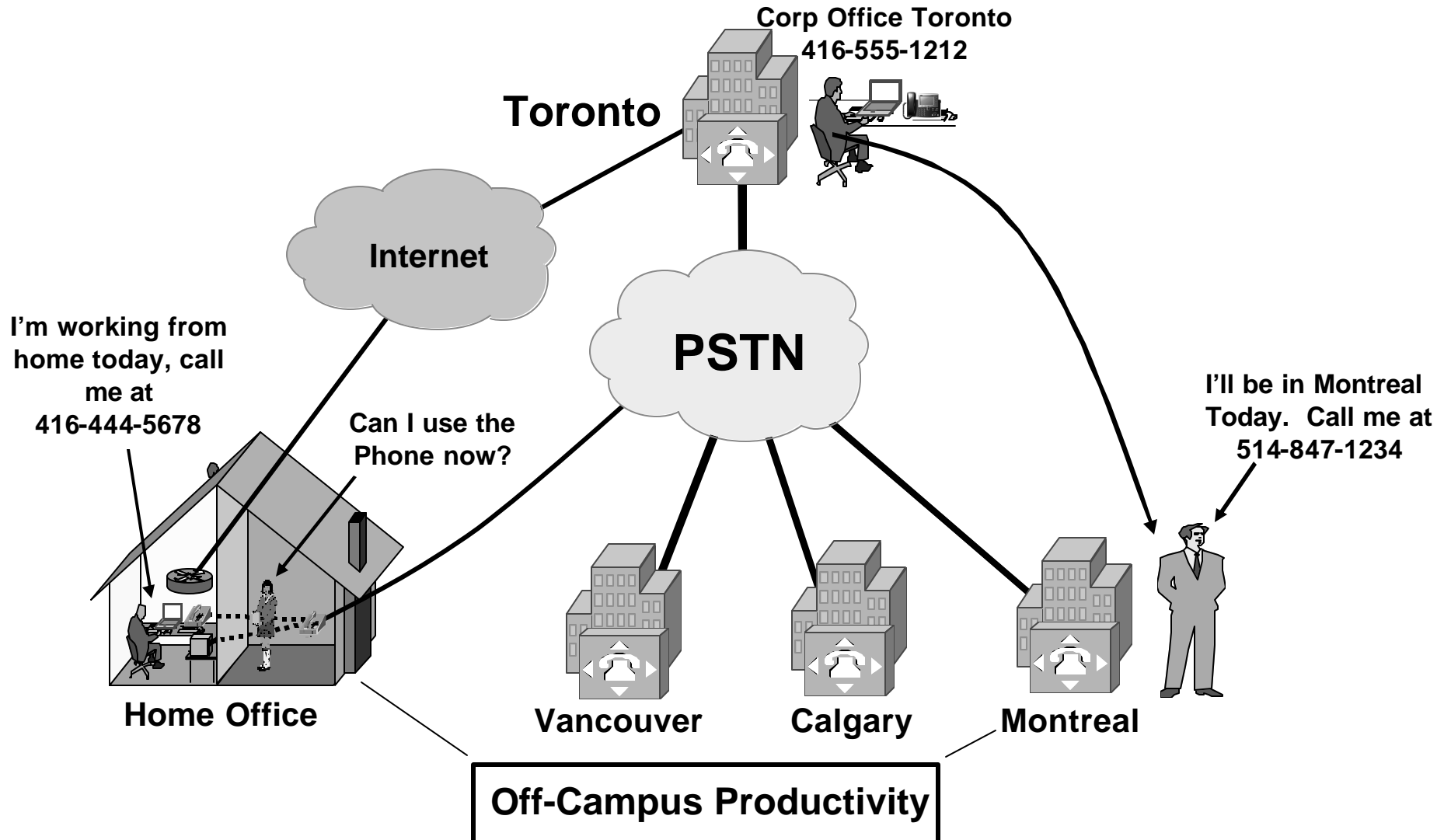
Cable Modem Services

The Obvious… The Internet!

- **Internet access from 56Kbps up to 5Mbps/1Mbps**

- **Business Internet services can give business traffic priority over residential customers.**

- **Cost Effective ($35/mo. for basic service)**

High-Speed Business Internet

Toronto

Corp Office Toronto
416-555-1212

Cable Router

CMTS

Internet

PSTN

I'm working from
home today, call
me at
416-444-5678

I'll be in Montreal
Today. Call me at
514-847-1234

Can I use the
Phone now?

Home Office

Vancouver

Calgary

Montreal

Off-Campus Productivity
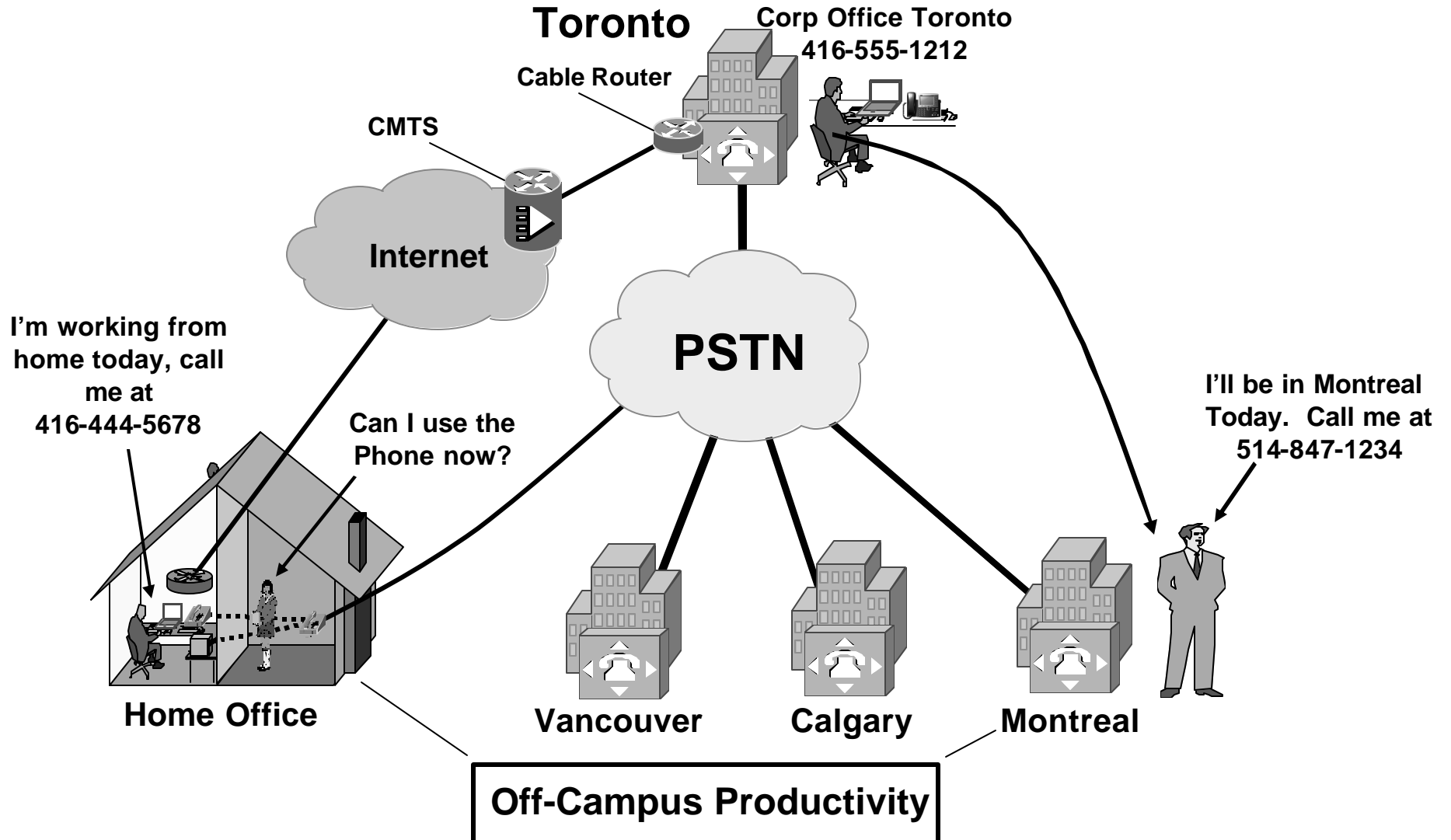
Cable Modem Services
VPN Technologies

VPN Remote Office

- **VPN Concentrator at main office.**

- **VPN Client device at remote offices.**

- **Leased-Line replacement.**

- **Secure, and scalable. More offices do not require more links at the main site.**

Cable Modem Services
VPN Technologies

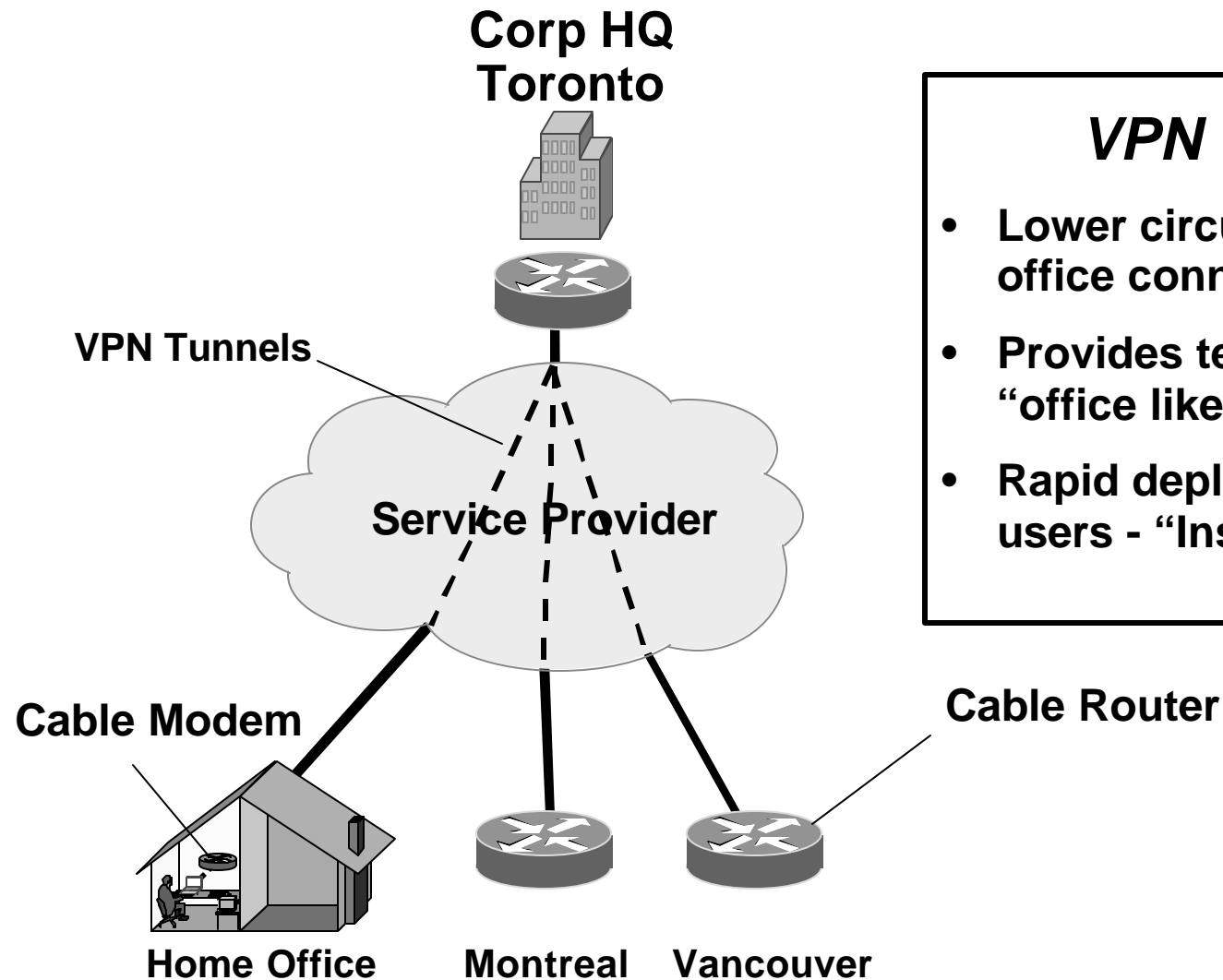## VPN Telecommuter

- **VPN Concentrator at main office can be the same used for remote workers.**

- **VPN Client Software is installed on laptops/PC's of remote workers.**

- **One-time passwords, and firewall enforcement provide added security.**

Mobility and VPN Solutions

Corp HQ Toronto

VPN Tunnels

Service Provider

Cable Modem

Home Office   **Montreal**   **Vancouver**

Cable Router

VPN Solutions

- **Lower circuit cost for branch office connectivity**

- **Provides teleworkers with "office like" data connectivity**

- **Rapid deployment of nomadic users - "Instant Office"**

Future Services

V3PN

- **Voice and Video enabled VPN's**

- **Requires QoS and SLA Guarantees in the Service Provider Core**

Voice and Video Enabled VPN – V³PN

Branch Office

SP

VPN Tunnels

Teleworker

VPN – Virtual Private Networks

VPN   **QoS**

V³PN

Voice Video

PSTN

Private IP WAN

HQ

IP Telephony

Branch Office

V3PN SP

VPN Tunnels

Teleworker

V3PN - Voice/Video enabled VPN
Extended Enterprise Mobility
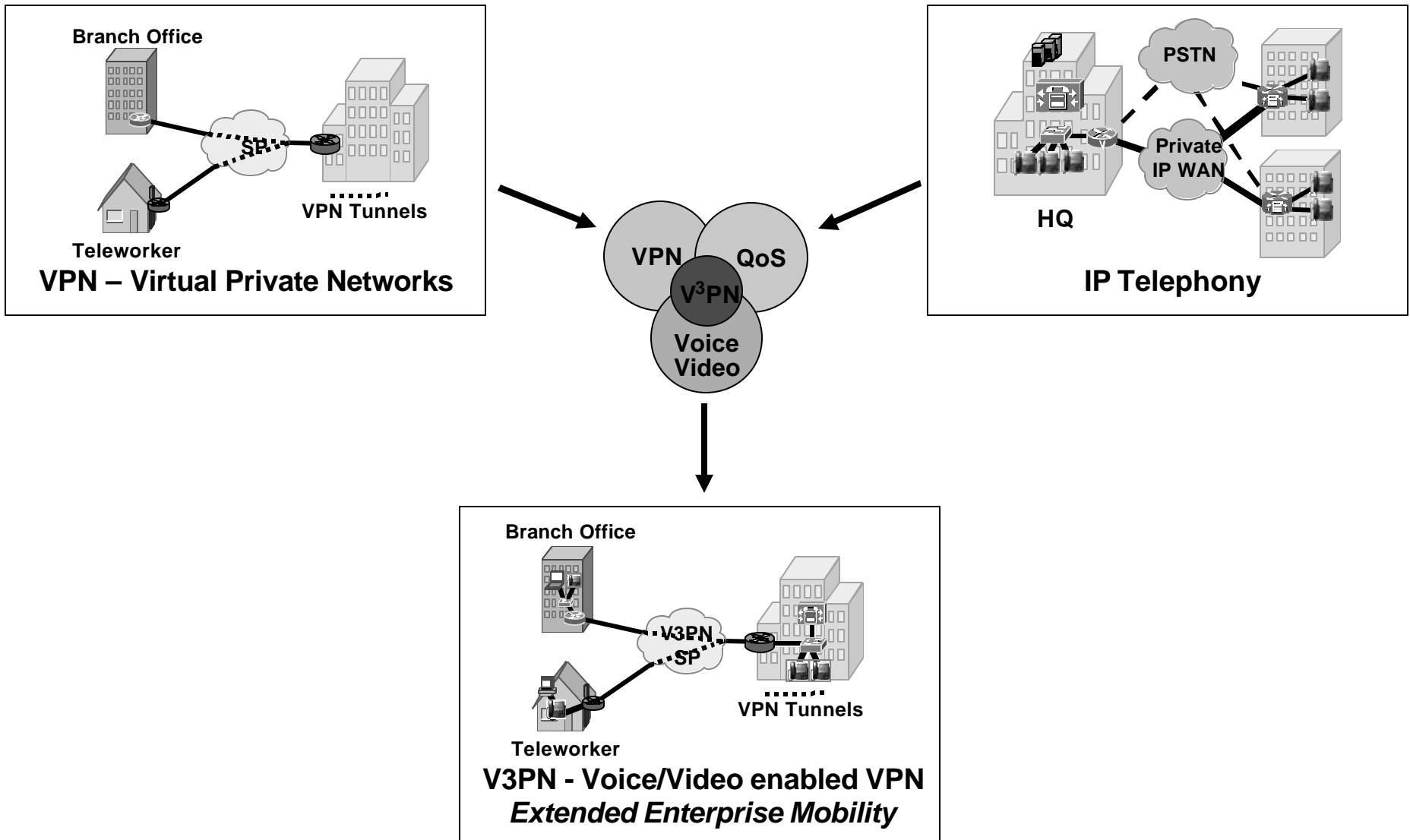
IP Telephony and VPN

Voice and Video Enabled VPN – V^{3}PN

Corp HQ Toronto

Hello this is John

John

Corp Office TO 416-555-1212

I need to call John 416-555-1212

PSTN

QoS enabled VPN (V3PN) over Cable Service Provider

Hello this is John

Home office # 416-555-1212

Montreal

Vancouver

Hello this is John
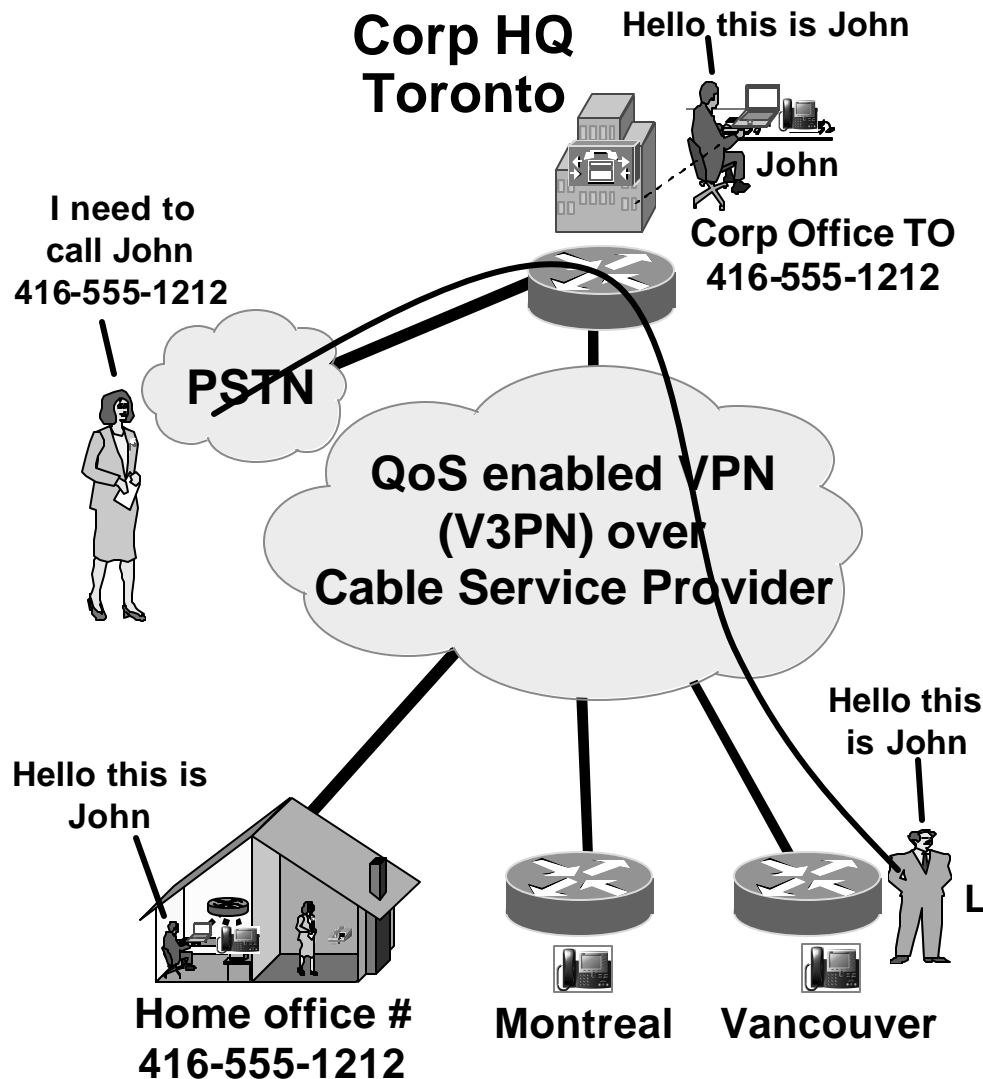
Log into phone and phone takes profile of 416-555-1212


V3PN Solutions

- **Lowers costs and increases teleworker productivity**

- **Cisco Powered Network (CPN) Service Provider partners carry voice/video with toll quality SLA's**

- **Same network connectivity at home as in corp office (voice, video and data)**

Enterprise Benefits of V³PN
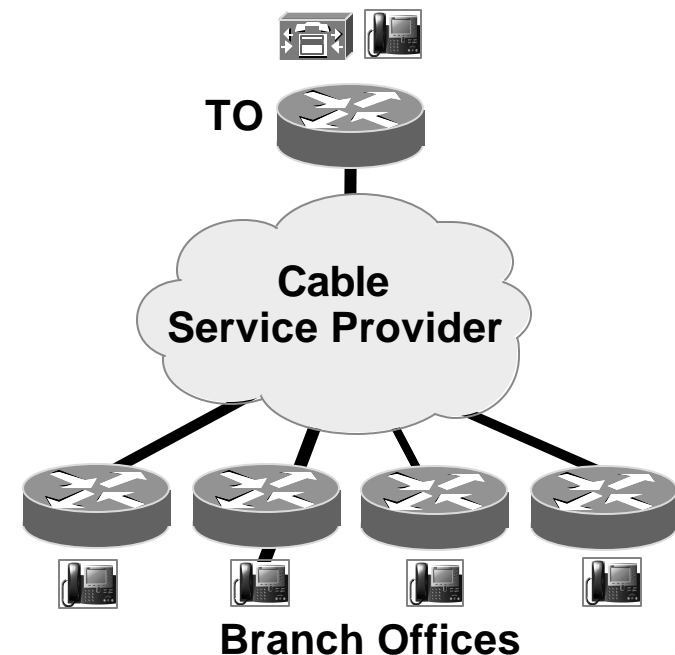## Lower Cost to Network Branch Offices

Before: Private Frame Relay	After: Voice and Video enabled VPN

Before:
Private Frame Relay

TO

Private Frame Relay

Branch Offices

After:
Voice and Video enabled VPN

TO

Cable Service Provider
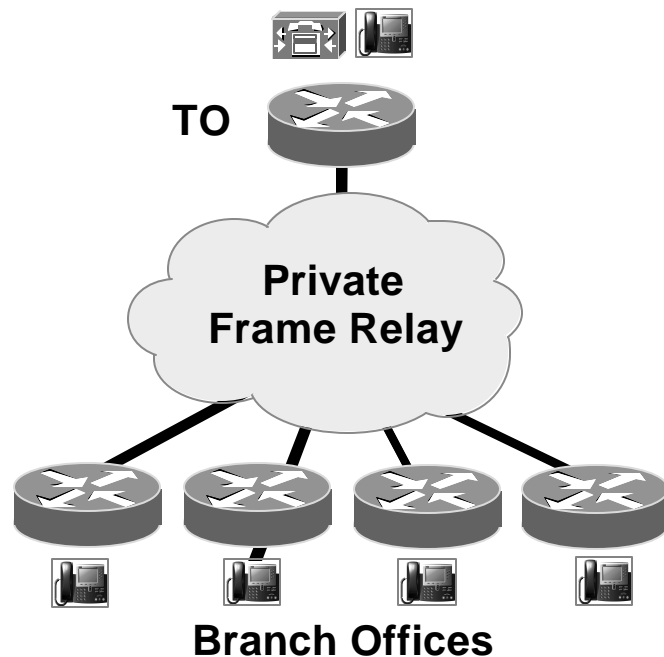
Branch Offices

- **23 sites – $38k per month**
- **Sub T1 access for branches**
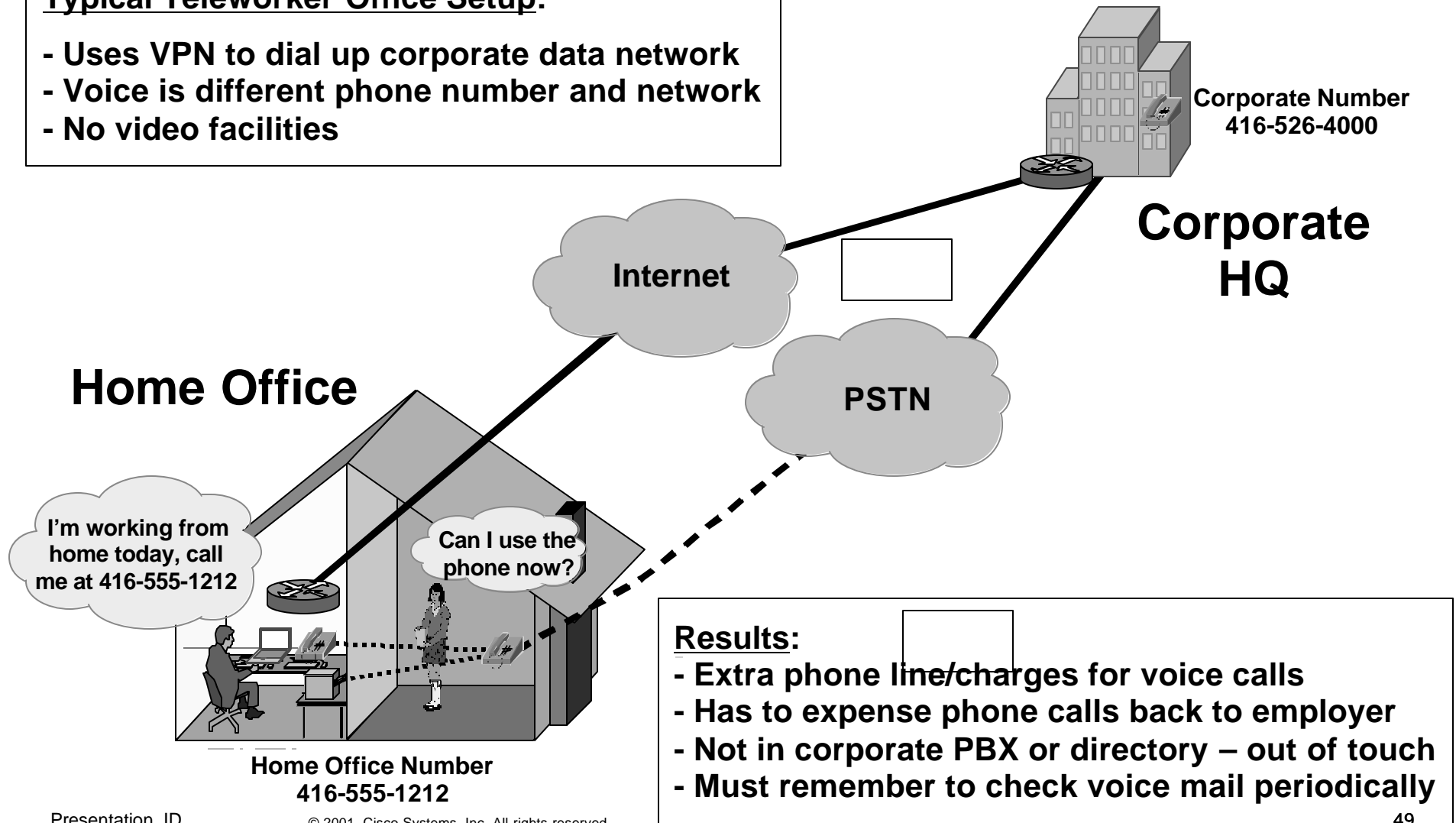- **1 month installation time**

- **23 sites – $24k per month**
- **T1 access for branches**
- **2 week installation time**

Teleworker Example
Today

Typical Teleworker Office Setup:

- **Uses VPN to dial up corporate data network**
- **Voice is different phone number and network**
- **No video facilities**

Corporate Number
416-526-4000

Corporate HQ

Internet

PSTN

Home Office

I'm working from home today, call me at 416-555-1212

Can I use the phone now?

Home Office Number
416-555-1212

Results:
- **Extra phone line/charges for voice calls**
- **Has to expense phone calls back to employer**
- **Not in corporate PBX or directory – out of touch**
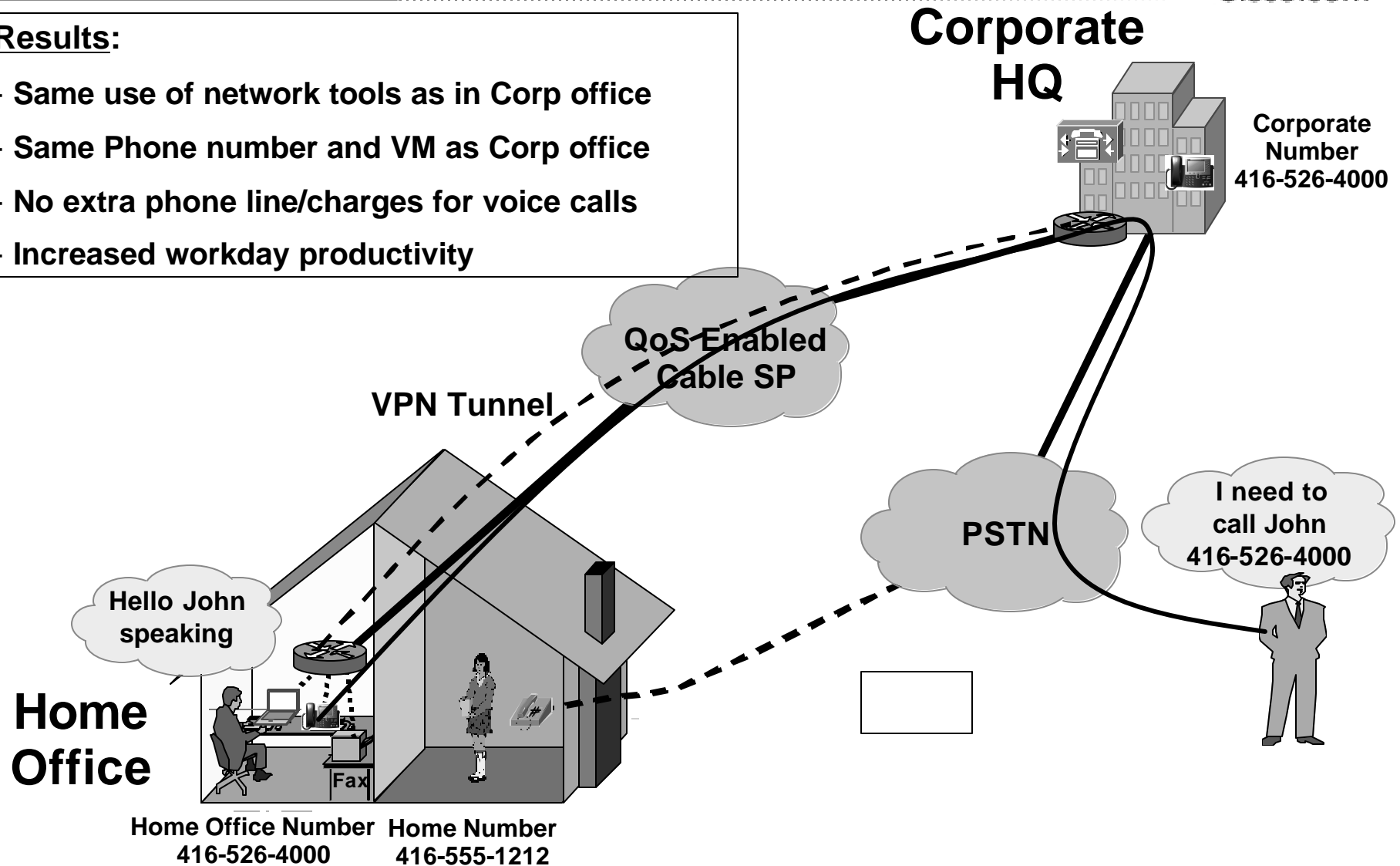- **Must remember to check voice mail periodically**

Teleworker Example
Tomorrow – IP Telephony Enabled Teleworker

Results:

- **Same use of network tools as in Corp office**

- **Same Phone number and VM as Corp office**

- **No extra phone line/charges for voice calls**

- **Increased workday productivity**

Corporate HQ

Corporate Number 416-526-4000

QoS Enabled Cable SP

VPN Tunnel

PSTN

I need to call John 416-526-4000

Hello John speaking

Home Office

Fax

Home Office Number 416-526-4000

Home Number 416-555-1212

IP Telephony for Teleworker
For Legacy PBX Environments

Cisco.com

Corporate HQ

How it Works

1. **Analog line configured is same # as Corp Office Legacy PBX Phone**
2. **Analog line configured to go through gateway and ring teleworker's home IP phone**
3. **Corp Office number called – Rings in both Places**
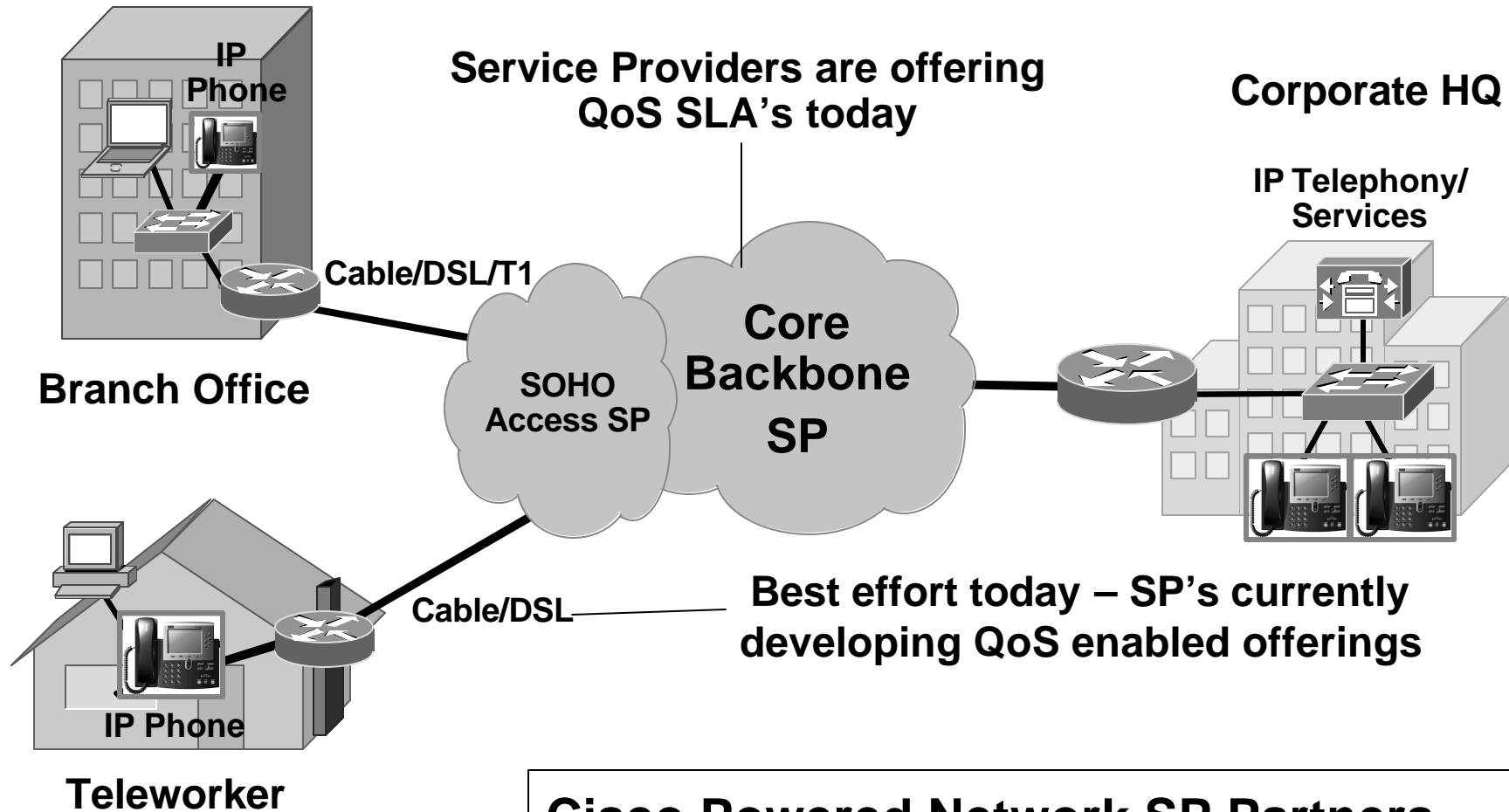4. **Possibly no VM light depending on legacy PBX vendor**

Corporate Office Number
416-526-4000

CallManager

VoIP GW

Legacy/Proprietary Phone Line

QoS Enabled SP

VPN Tunnel (V3PN)

Legacy PBX

Analog Phone Line Same as Corp Office Number 416-526-4000

PSTN

Hello John speaking

I need to call John 416-526-4000

Fax
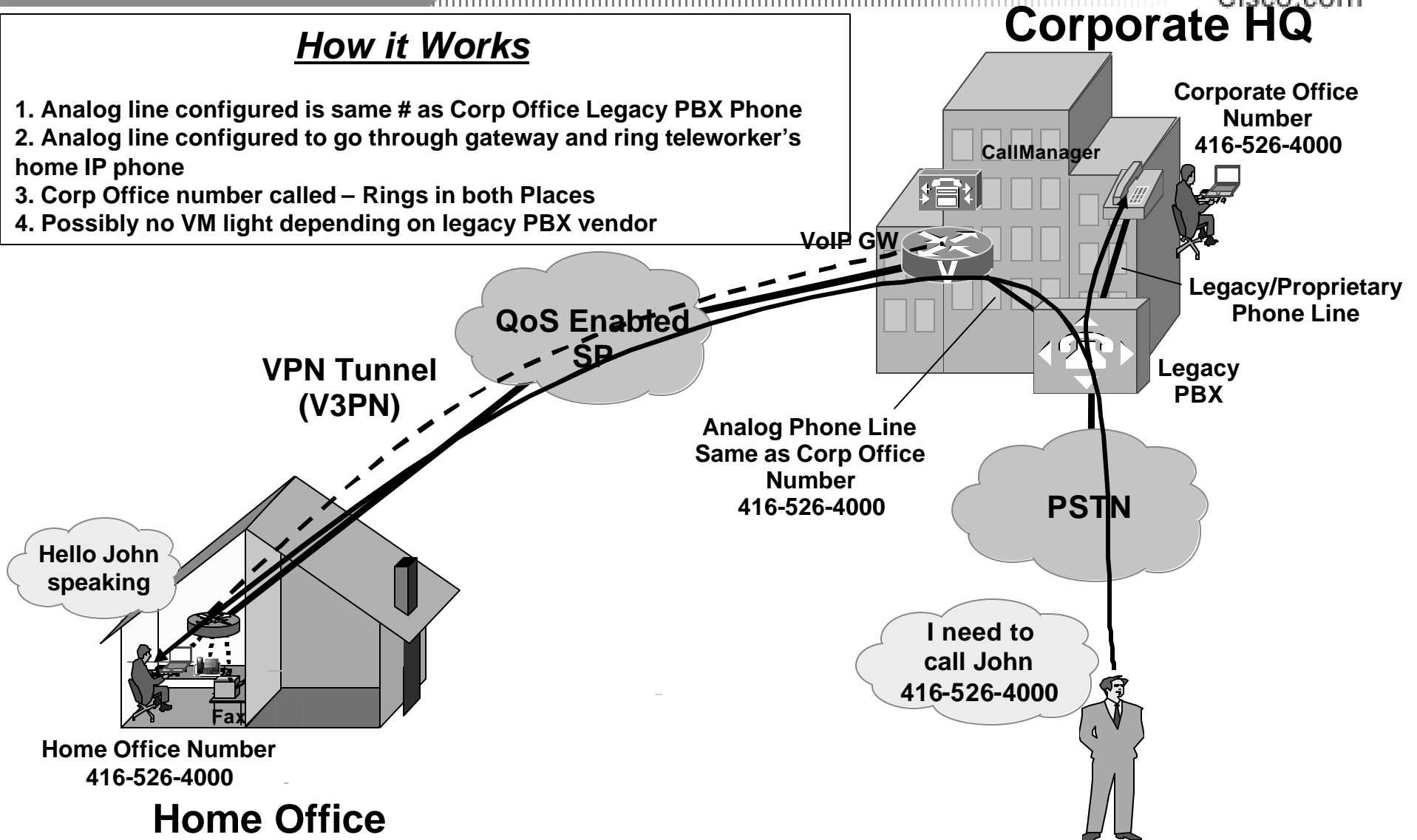
Home Office Number
416-526-4000

Home Office

V³PN (VoIP/Video Enabled IPSec VPN)
Enterprises Requiring SP QoS

IP Phone

Service Providers are offering QoS SLA's today

Corporate HQ

IP Telephony/ Services

Cable/DSL/T1

Core Backbone SP

SOHO Access SP

Branch Office

Cable/DSL

Best effort today – SP's currently developing QoS enabled offerings

IP Phone

Teleworker

Cisco Powered Network SP Partners

http://www.cisco.com/pcgi-bin/cpn/cpn_pub_bassrch.pl

Gartner Group Research Results
Facts on Companies that have Installed VPNs
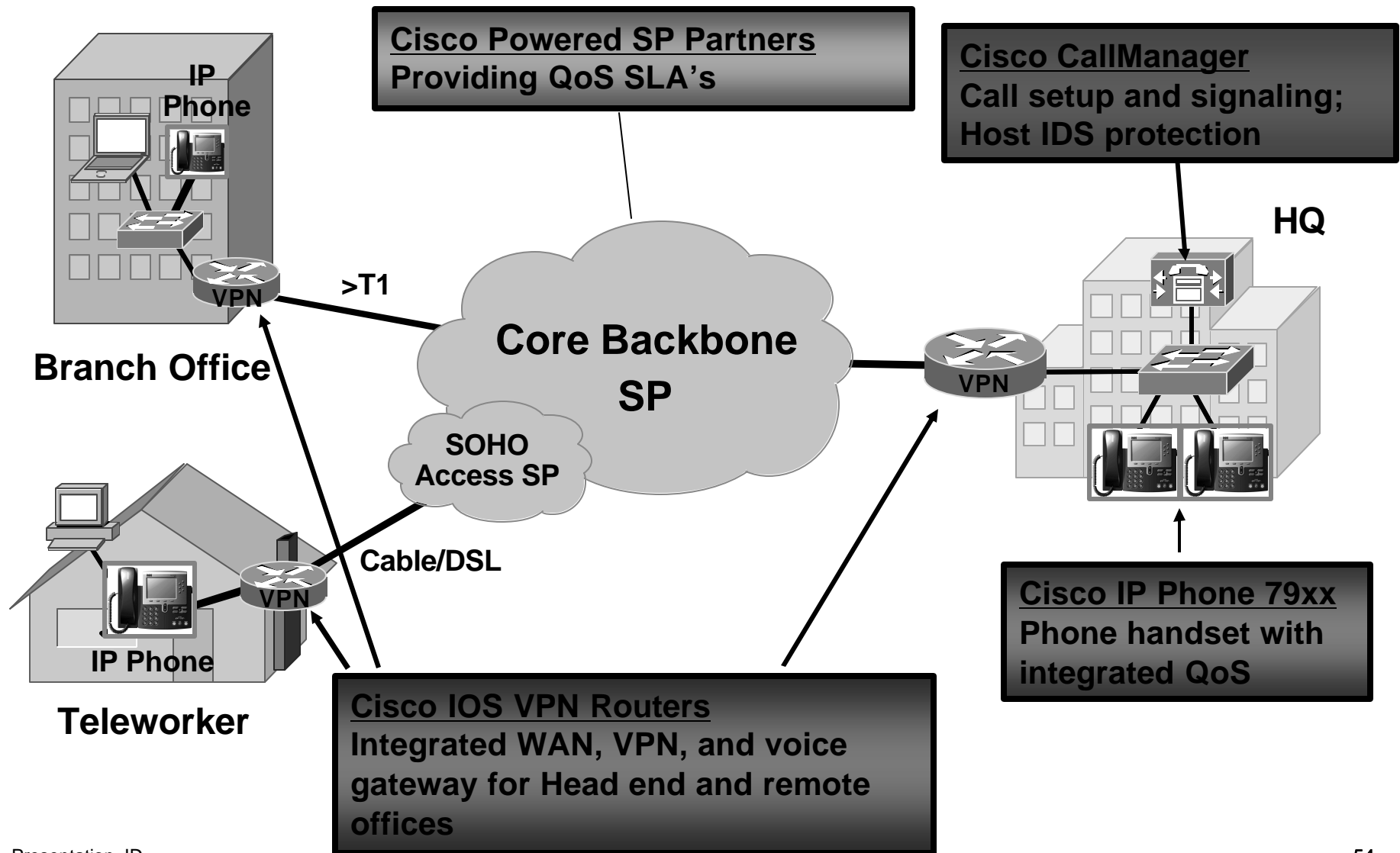
VPNs provide the most cost-effective, flexible and secure network infrastructure for converged voice, video and data
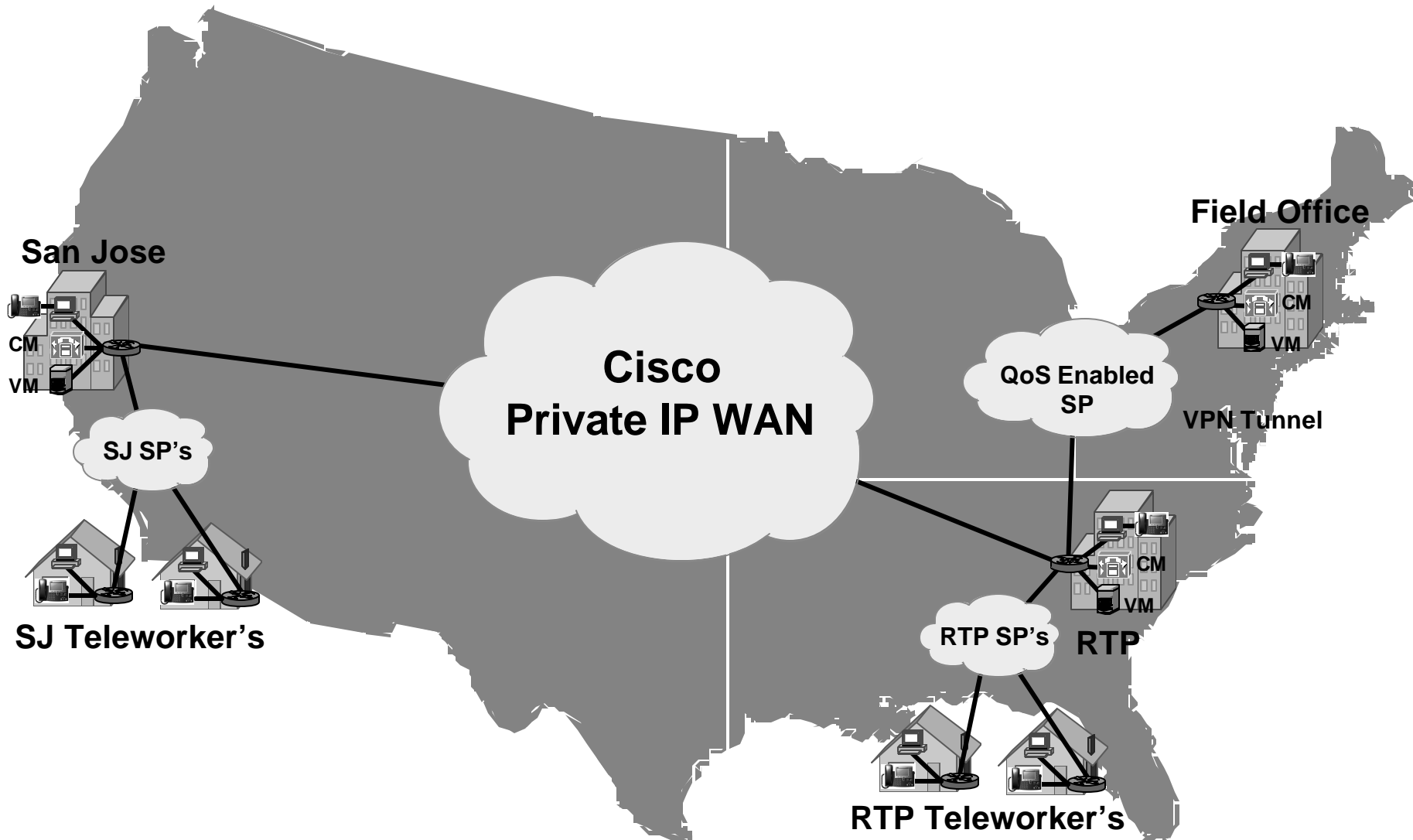
- **85% report higher levels of network security and faster connectivity**

- **The average ROI is 54% over an 18 month period**

- **Almost 90% report experiencing cost-savings over their previous solution**

- **Three hours saved per employee per week**

- **70%+ using VPN extranets site improved communications with their customers and partners**

- **75% + say that VPNs make supporting remote users easier for IT staff**

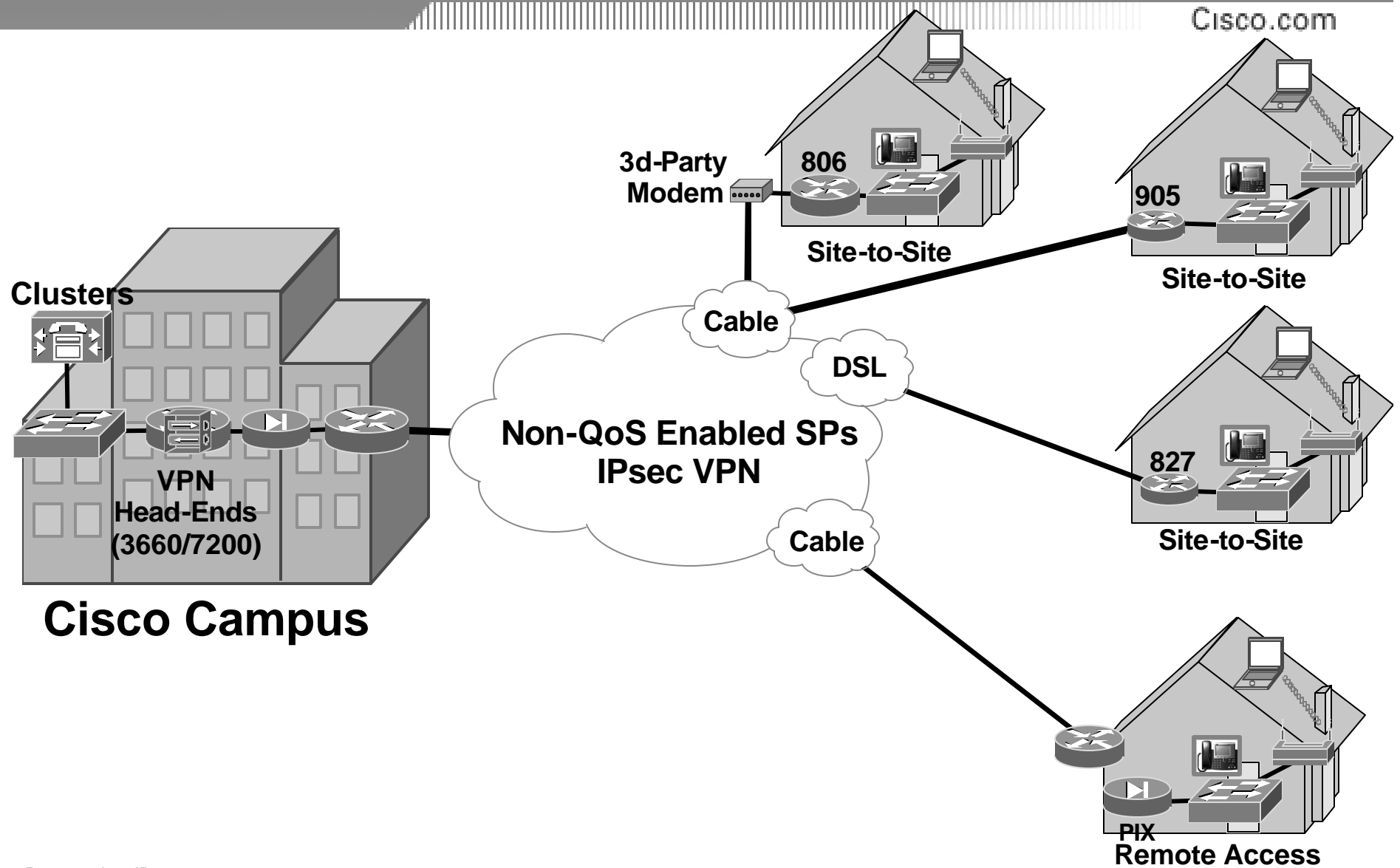# *Only Cisco Delivers End-to-End, Fully Interoperable V³PN Network Solution*

IP Phone

Cisco Powered SP Partners
Providing QoS SLA's

Cisco CallManager
Call setup and signaling;
Host IDS protection

HQ

VPN >T1

Branch Office

Core Backbone SP

VPN

SOHO Access SP

Cable/DSL

VPN

IP Phone

Teleworker

Cisco IP Phone 79xx
Phone handset with
integrated QoS

Cisco IOS VPN Routers
Integrated WAN, VPN, and voice
gateway for Head end and remote
offices

Cisco Internal V³PN Deployment

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Cisco Teleworkers

Current Deployment Examples

3d-Party Modem

806

Site-to-Site

905

Site-to-Site

Clusters

Cable

DSL

Non-QoS Enabled SPs IPsec VPN

VPN Head-Ends (3660/7200)

827

Site-to-Site

Cable
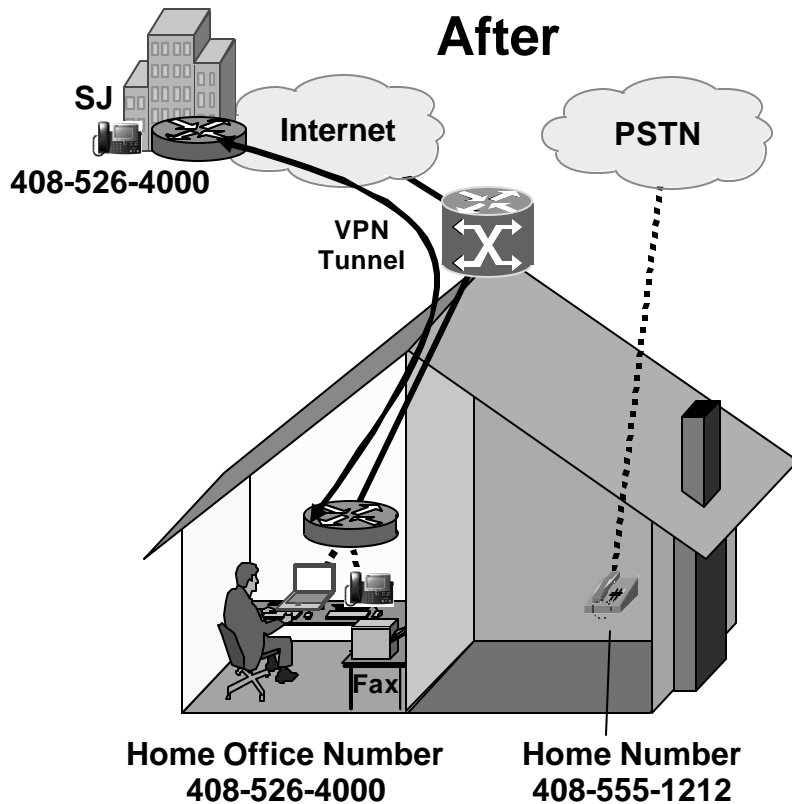
Cisco Campus

PIX
Remote Access

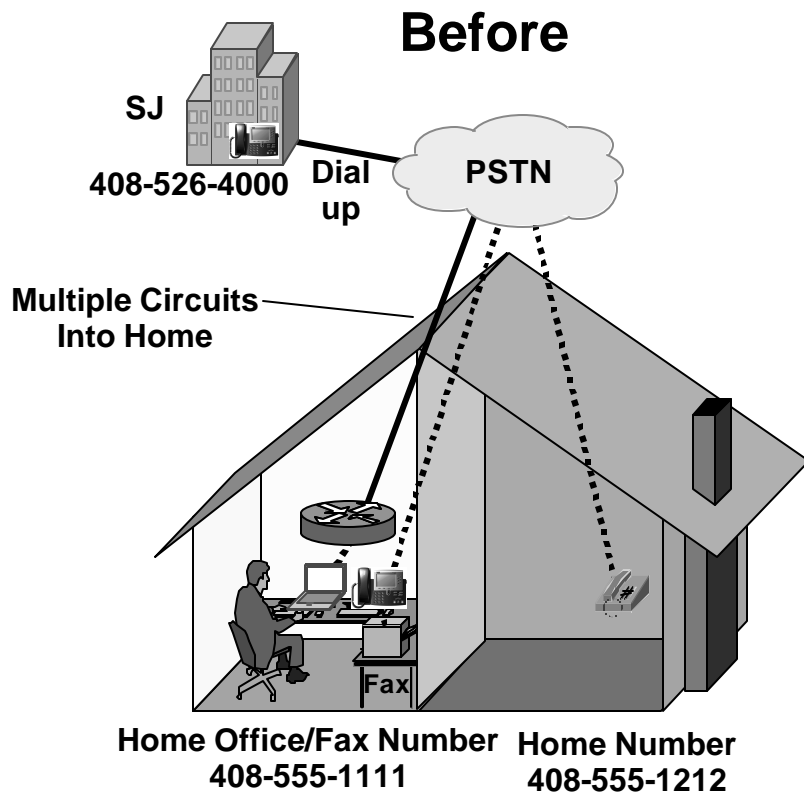# *Cisco Internal Requirements*

- **Many Teleworkers requiring same IP Telephony requirements as in Corp Office**

    Development, Tech Writers, Sales etc.

- **Lower cost on expensed Home phone bills**

- **Increased workday productivity**

- **Edge QoS with a "Best Effort" SP acceptable for benefits gained – Toll Quality >99% of the time**

Cisco Internal Teleworker Deployments

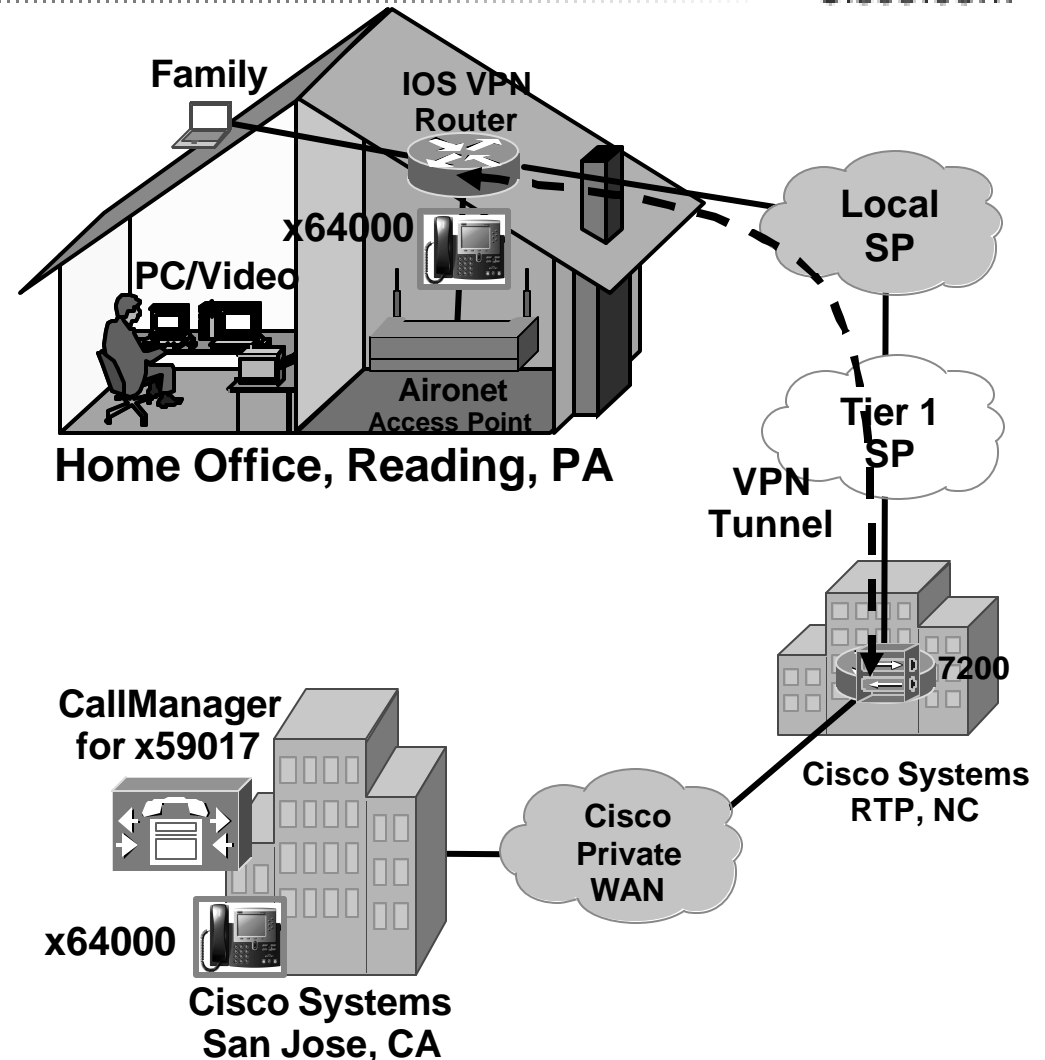## Before

SJ
408-526-4000 Dial up

PSTN

Multiple Circuits Into Home

Fax

Home Office/Fax Number
408-555-1111

Home Number
408-555-1212

- **Two PSTN Lines – Home + Work**
- **Work number different than Corp office**
- **Work number shared by Fax**
- **Expensed Work phone bill - $200/month**

After

SJ
408-526-4000

Internet

PSTN

VPN Tunnel

Fax

Home Office Number
408-526-4000

Home Number
408-555-1212

- **One PSTN Line – Home**
- **Work number same as Corp office**
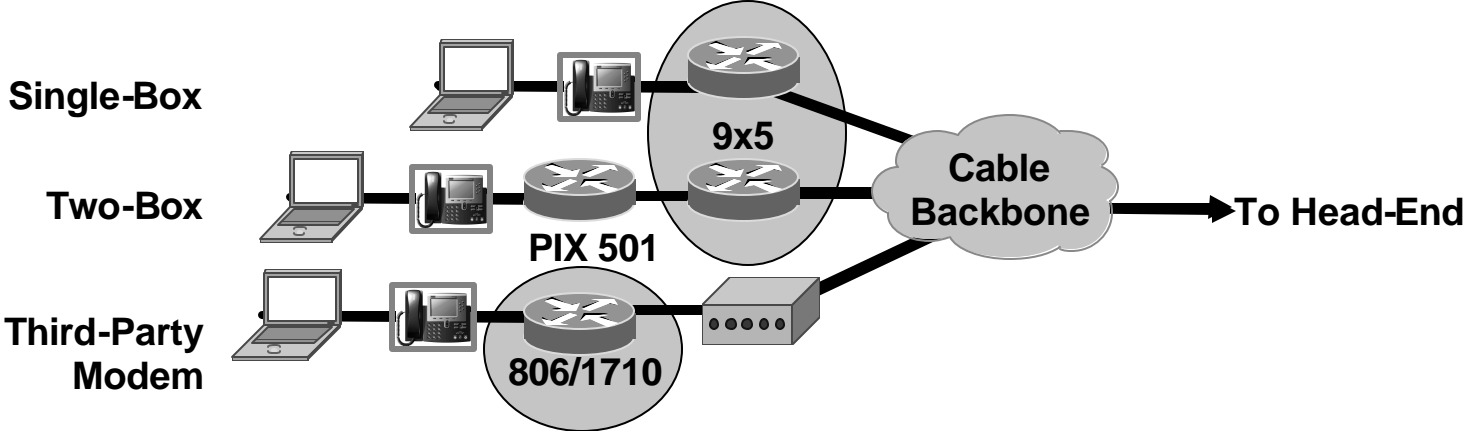- **Separate Fax number**
- **Expensed Work phone bill - $0**

A Cisco SOHO Site-to-Site VPN Site

- **Transparent data, voice and video as if located in San Jose**

- **Firewall and VPN tunnel termination on IOS router**

- **QoS configuration**
  - LLQ on WAN Interface
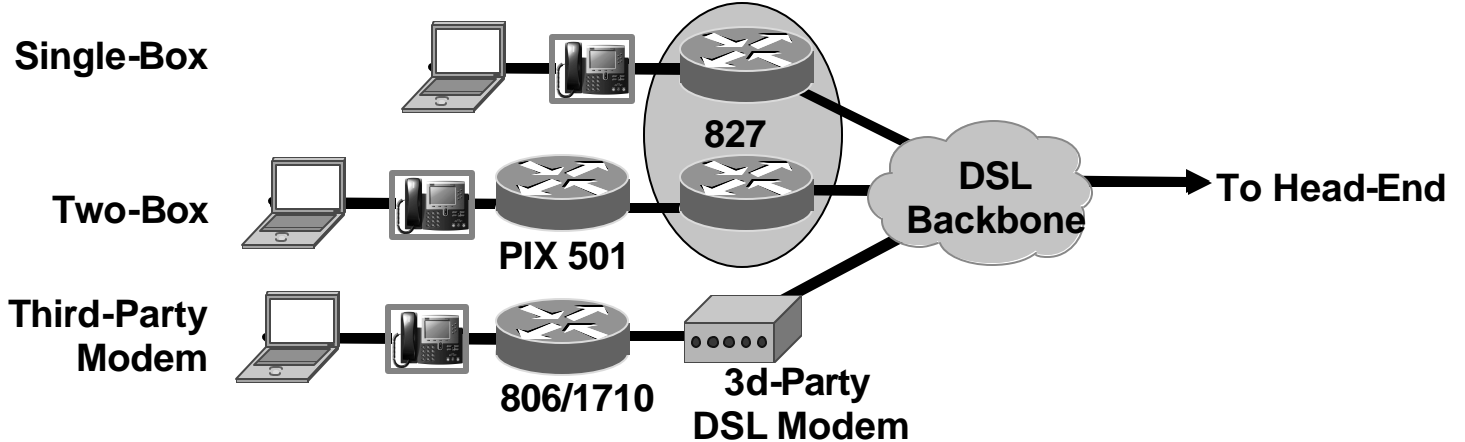 - Service Provider "best effort"

Family

IOS VPN Router

x64000

PC/Video

Aironet Access Point

Home Office, Reading, PA

Local SP

Tier 1 SP

VPN Tunnel

7200

Cisco Systems RTP, NC

CallManager for x59017

Cisco Private WAN

x64000

Cisco Systems San Jose, CA

Cisco Internal Deployment Models

Single-Box

9x5

Two-Box

PIX 501

Cable Backbone

To Head-End

Third-Party Modem

806/1710

DSL

Cable

Single-Box

827

Two-Box

PIX 501

DSL Backbone

To Head-End

Third-Party Modem

806/1710

3d-Party DSL Modem

3rd Party Cable/DSL Modems
Cisco IOS VPN Router with Traffic Shaping Required

10/100m Ethernet   **Shaped**   **128k Uplink**

Cable
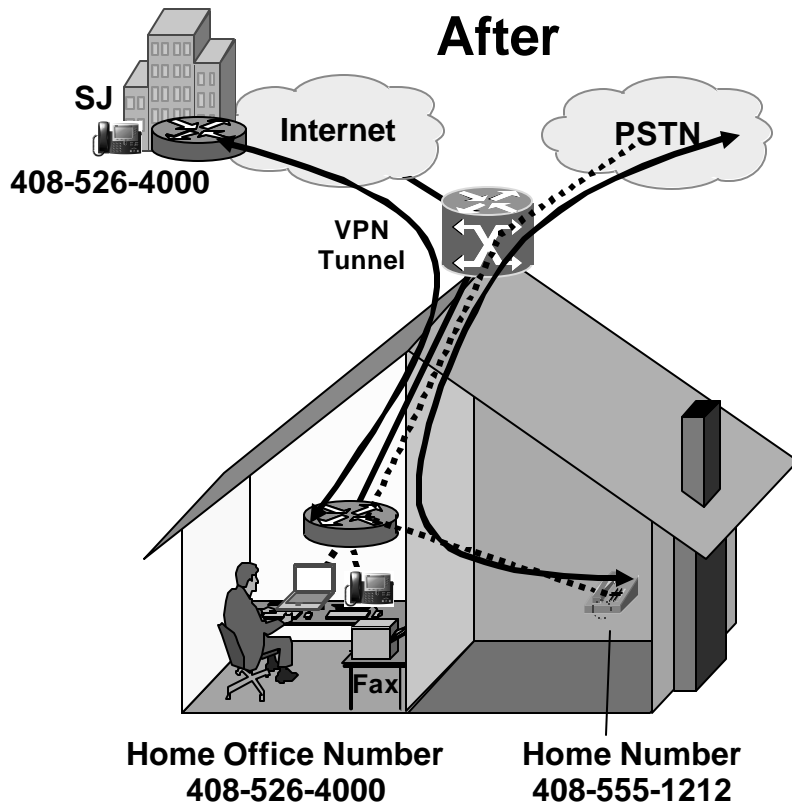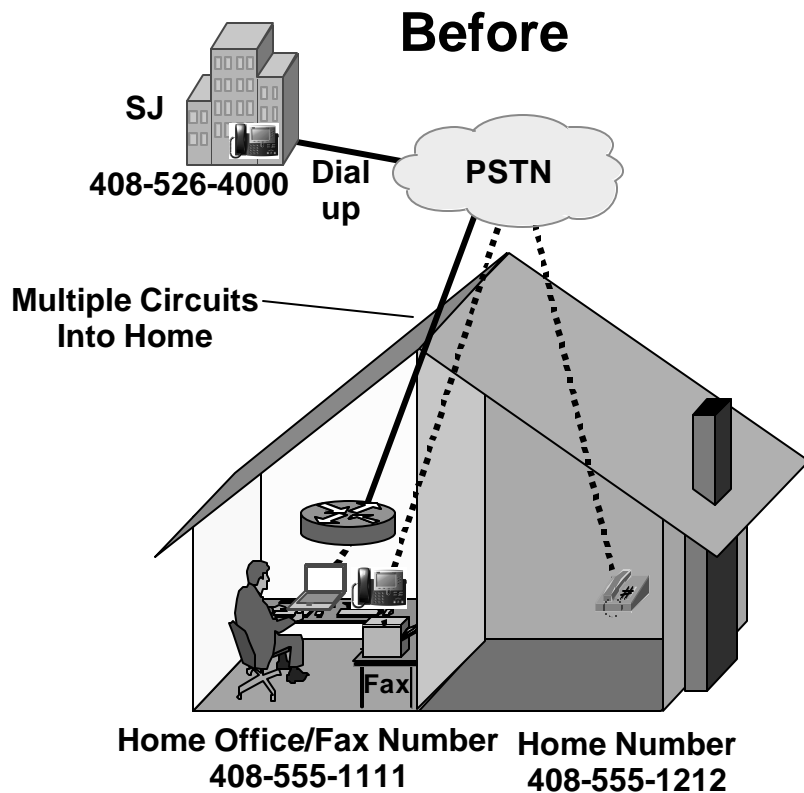Backbone

806/1710

**3d-Party
DSL/Cable Modem**

To Head-End
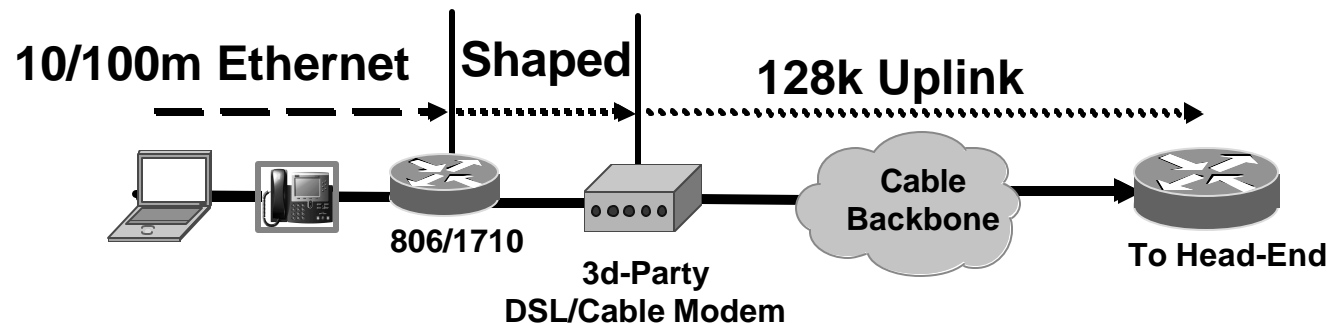
- ## Traffic shaping to uplink speed

- ## Avoids uplink congestion

- ## Ensure that QoS honored

Cisco Internal Teleworker Deployments

Before

SJ
408-526-4000

Dial up

PSTN

Multiple Circuits Into Home

Fax

Home Office/Fax Number
408-555-1111

Home Number
408-555-1212

- **Two PSTN Lines – Home + Work**
- **Work number different than Corp office**
- **Work number shared by Fax**
- **Expensed Work phone bill - $200/month**

After

SJ
408-526-4000

Internet

PSTN

VPN Tunnel

Fax

Home Office Number
408-526-4000

Home Number
408-555-1212

- **One PSTN Line – Home**
- **Work number same as Corp office**
- **Separate Fax number**
- **Expensed Work phone bill - $0**

Value of V³PN Solutions from Cisco
Summary

Delivers operational efficiencies by:

Reducing network infrastructure, bandwidth, and operating costs

Delivering corporate voice and data network connectivity to more sites and users

Cost-effectively increasing secure bandwidth to enable new converged applications

Provides greater network security through:

Encryption of voice and video streams

Authentication and intrusion protection on network devices

Stateful inspection of voice and video traffic

Provides an E-Business capable network with:

Voice and video enabled VPN with end-to-end device interoperability

Deployment model for service providers and enterprises

Part of the Cisco Multi-Service VPN Solutions Suite

Delivers voice and video across IP, IPSec, and MPLS

For More Information…

- **V^{3}PN**

  www.cisco.com/go/v3pn

- **Cisco VPN Routers**

  800, 1700, 2600, 3600, 3700, 7100, 7200, 7400VPN Series Routers

  http://www.cisco.com/warp/public/779/largeent/learn/technologies/vpn/site2site.html

- **Cisco Telephony Products**

  http://www.cisco.com/warp/public/779/largeent/learn/technologies/voice.html

- **Cisco Security Products**

  www.cisco.com/go/security

…For More Information…

- ## Cisco Cable Products

  http://www.cisco.com/warp/public/779/servpro/solutions/cable/

  uBR9xx Cable Access Routers

  http://www.cisco.com/en/US/products/hw/cable/ps2221/index.html

- ## DOCSIS Spec.'s

  CableModem.org http://www.cablemodem.org/

  CableLabs http://www.cablelabs.org/