National Communications System (NCS)

Local Loop Overview

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Presentation Contents

I. Telecom Plant Basics

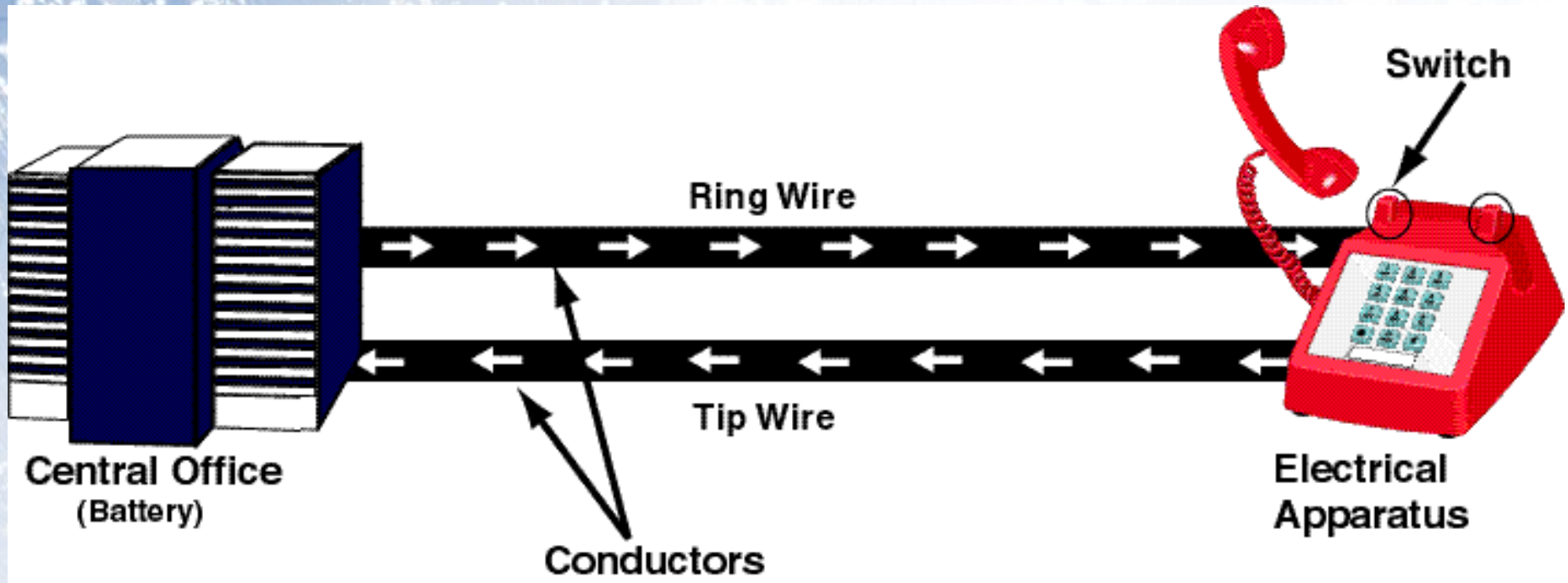
Main Components of a Telecom Network

Outside Plant (OSP) – buried and aerial cables, poles, manholes, and other structures and in customer premises.

Central Office (CO) – a building equipped with switches, routers and many other devices to support the outside plant and to connect to other central offices.

Inter-Office Facilities (IOF) – equipment and cables used to interconnect central offices.

The Basic Telephone Circuit



Twisted Pairs

A pair of copper conductors that are used to transmit electrical signals. They are twisted around each other to cancel electromagnetic interference that causes cross-talk.

In telecommunications, the unshielded twisted pair (UTP) is commonly used to transmit telephony and data in analog and in digital forms.

We use the word *pairs* to indicate the plural of twisted pair.

Twisted Pairs (continued)

The conductor pairs must be insulated from each other. In the last 35+ years, the insulation has been plastic, and each pair has been color coded to identify it from others.

Twisted Pairs (continued)

Many older cables, however, have paper-like insulation that is known as *pulp insulation*.

Pulp-insulated conductors are very susceptible to damage from water, so when placed in underground conduits, they are kept dry via pressurized air.

Applications of Twisted Pairs

The electric signals transmitted on twisted pairs can be analog or digital. The following are the most common applications of twisted pairs in telecommunications.

POTS

Plain Old Telephone Service (POTS), requires one twisted pair per telephone line.

The POTS signals are analog, which means that the electric flow is continuous, even as the voltage and amperage vary.

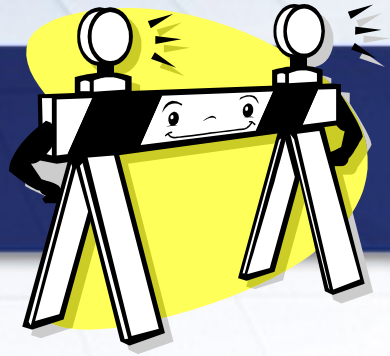
Applications of Twisted Pair (continued)

T-1

A set of two twisted pairs can also be conditioned to transmit a 1.5Mbps digital signal called a DS1.

Such lines are known as T-1 lines.

T-1 lines can transport 24 digitized POTS lines in 64Kbps digital signals called DS0 (D-S-zero).



Applications of Twisted Pair (continued)

ISDN

Twisted pairs are also used to transmit *Integrated Services Digital Network* (ISDN) in two forms:

- *Basic Rate Interface* (BRI) provides a 128Kbps digital signal with **2** *bearer* channels for information and 1 *data* channel for overhead (known as 2B+D)

- *Primary Rate Interface* (PRI) provides a 1.5Mbps digital signal with 23 bearer channels for information and one data channel for overhead (known as 23B+D)

Applications of Twisted Pair (continued)

DSL

Twisted pairs can be used to provide *Digital Subscriber Line* (DSL) service. DSL uses discrete multi-tone modulation (DMT) to generate a digital signal.

DSL can be provided in many different downstream line rates, ranging from to 256Kbps to 24Mbps.

Upstream rates range from 128Kbps to 1.5Mbps.

Applications of Twisted Pair (continued)

Power

Twisted pairs can also be used to provide electric power to remote equipment.

This is done in *fiber-to-the-curb* (FTTC) architectures, which will be discussed later.

Fiber

Fiber optics consists of strands made of highly pure glass.

The purity of the glass and the consistency of the geometry of the fiber strand, allow light to be transmitted through it for long distances.

These characteristics make fiber optic strands an ideal method for transmitting data at very high rates.

Cable

Multiple twisted copper pairs are wrapped into bundles known as *binder groups,* and the binder groups are encased in tubular sheathing. This is known as cable.

Binder groups in most modern cables are made up of 25 twisted pairs.

A twisted pair cable may contain from 1 to 168 binders, for a total of 25 to 4200 pairs (i.e., 25 pairs per binder).

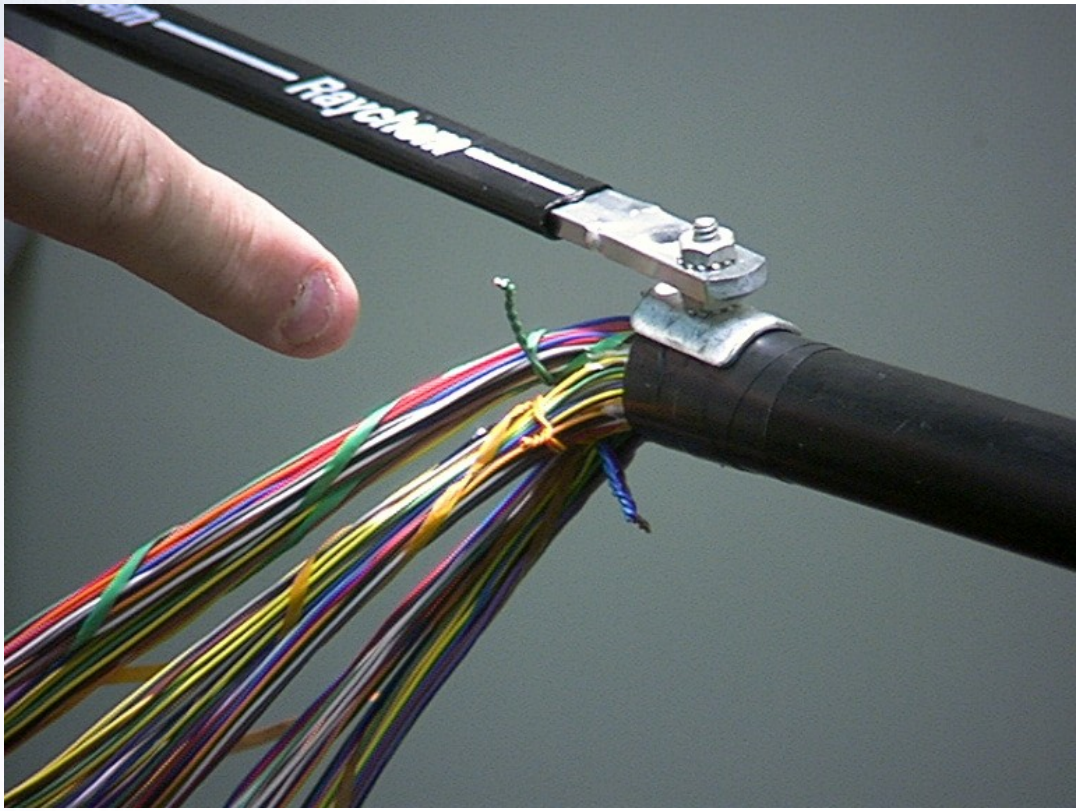
Cable (continued)

The tubular exterior of cable is known as the *cable sheath*. The sheath in modern cables is made of a rugged, highly durable plastic.

Some very old cables have sheaths that are made of lead, and they require special handling due to the toxicity of lead.

Cable (continued)

The picture below shows a cable with its twisted pairs exposed.



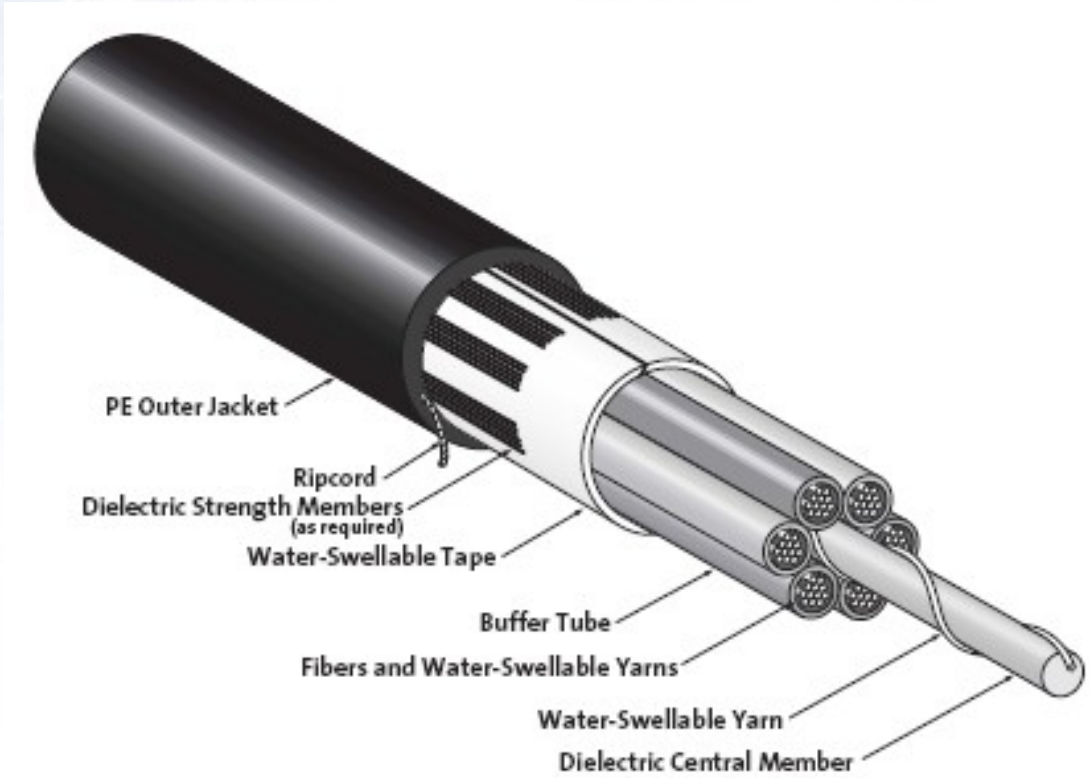
Cable (continued)

A cable may also contain fiber optic strands instead of twisted pairs.

Fiber cable, as it is known, is mostly used in high capacity transport.

Cable (continued)

The cable below shows a fiber sheath containing loose-tube fibers.



ALTOS All-Dielectric Gel-Free Cable | Drawing CPC-220/1/3

Cable (continued)

Fiber cables also have multiple bundles of fibers. Fiber bundles contain 12 fibers per binder group.

Fiber cables can contain from 2 to 864 fibers.

In recent years, fiber cable has also been used to serve individual customers in what is known as fiber-to-the-premises (FTTP), fiber-to-the-home (FTTH), and fiber-to-the-curb (FTTC) architectures.

These will be explained later.

Cable Specs

There are many types of cable specifications from which to choose.

The selection is determined by:

A) the signal transmission requirements
B) the required capacity
C) the environment in which the cable is to be installed

A) Transmission Requirements

The signal transmission requirements will determine:

- the American Wire Gauge (AWG) of the conductors (electrical signal)
  - 19 gauge
  - 24 gauge
  - 22 gauge
  - 26 gauge
- the design of the sheath
- the selection of shielding within the sheath
- the type of fiber used (optical signal)
  - multi-mode fiber
  - single-mode fiber

B) Capacity

The capacity requirement will determine the size of the cable in terms of the number of pairs or fibers that are required.

Size ranges include:

- Twisted pairs: 25 to 4200 pairs

- Fibers: 2 to 864 fibers

C) Environment

Cable is installed in many environments:

•In earth – known as *buried cable*; requires a special cable that has a gel filler to eliminate air gaps and thus prevent water intrusion.

•On pole lines – known as *aerial cable;* has an air core to reduce weight; the sheath can be hardened and provided with steel armor to protect it from squirrels.

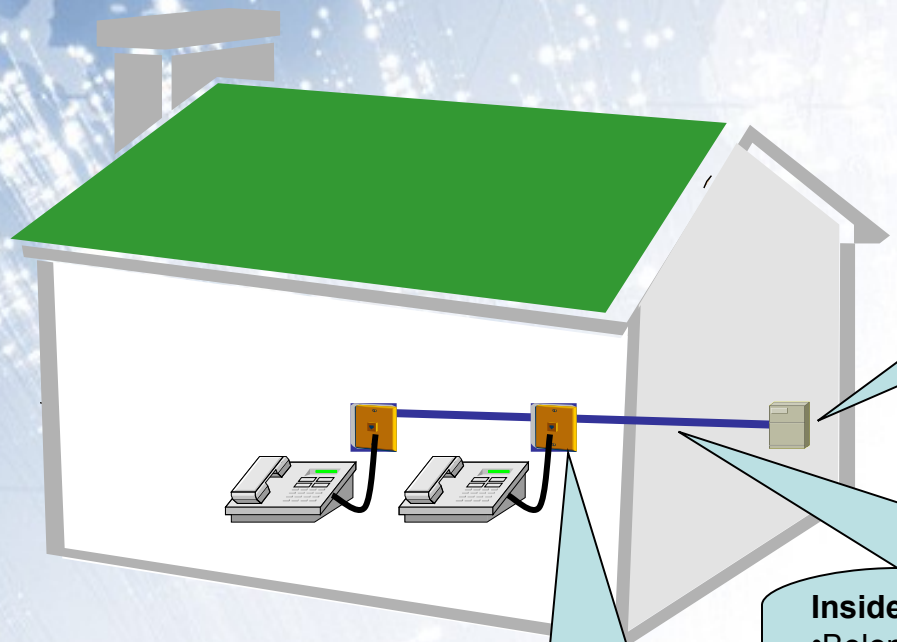
C) Environment (continued)

- In conduit runs with manholes – known as *underground cable*; gel-filled cable is used in modern installations

- Under water – known as *submarine cable*; requires a gel-filled interior and a special, extra rugged sheath design that includes layers of steel armor.

II. Copper Distribution

Customer Premises



Network Interface Device (NID):
Demarcation point between inside wiring and TELCO facilities. Serves as testing point to isolate problems in the circuit.

Inside Wiring:
- Belongs to the house
- Distributes telephony and DSL service throughout the structure
- Uses unshielded twisted copper pairs

Telephone Wiring Jack:
- Belongs to the house
- Connected to the inside wiring
- RJ11 connector is standard

Customer Premises

RJ11 Wall Jack

RJ11 Connector

Network Interface Device

Direct Feeder Architecture

Central Office (CO):
A building that houses electronic equipment such as switches and routers. The CO is at the center of the local network and it provides connections to the rest of the networks in the world.

Service Wire:
Connects the subscriber's NID to a distribution terminal. Can be aerial or buried. Also known as a drop wire. Come in 1, 2, or 5-pair capacity.

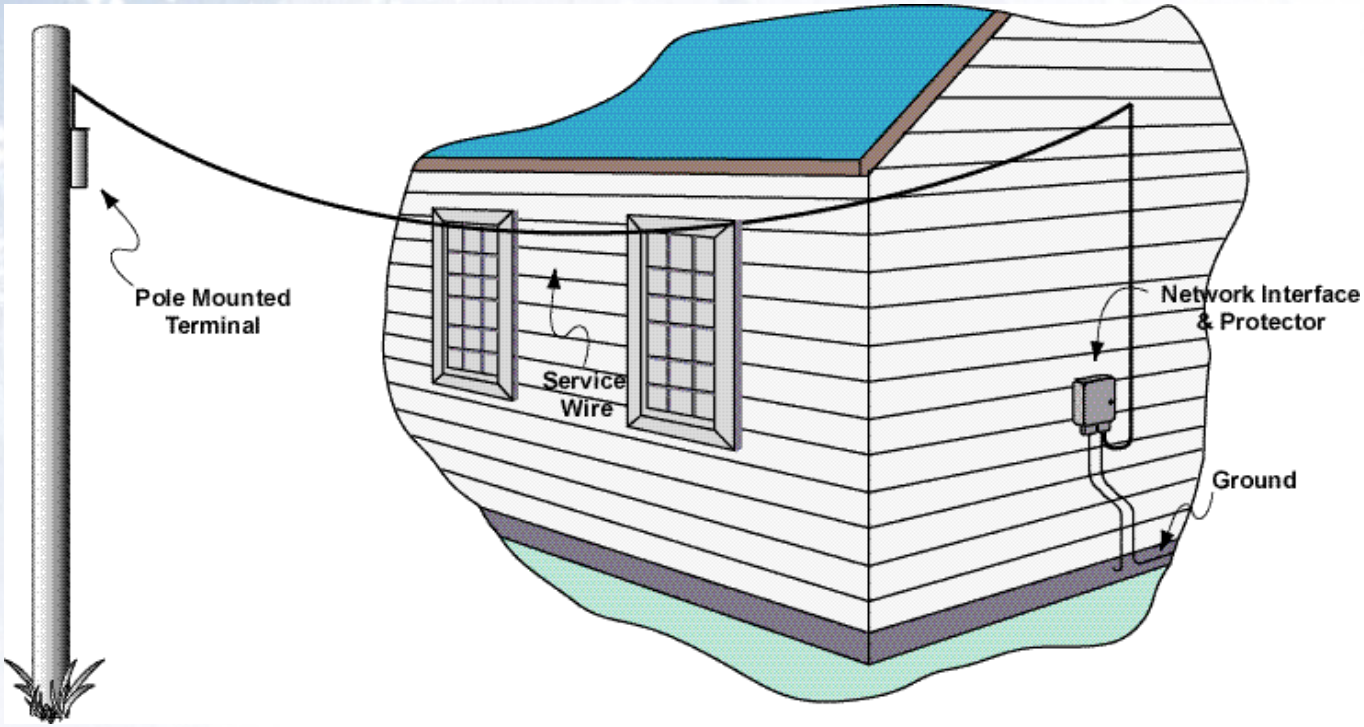
Distribution Terminal:
Used to access individual pairs in the cable and connect them to the subscriber's service wire. Can be pole mounted for aerial cable, or pedestal mounted for buried cable.

Feeder Cable:
Provides connectivity between the central office and the outside facilities. Referred to as Facilities 1 (F1).

Depending on the type used, they may contain 25 - 2000 copper pairs, & may have plastic or pulp insulated conductors, and gel or air fill.

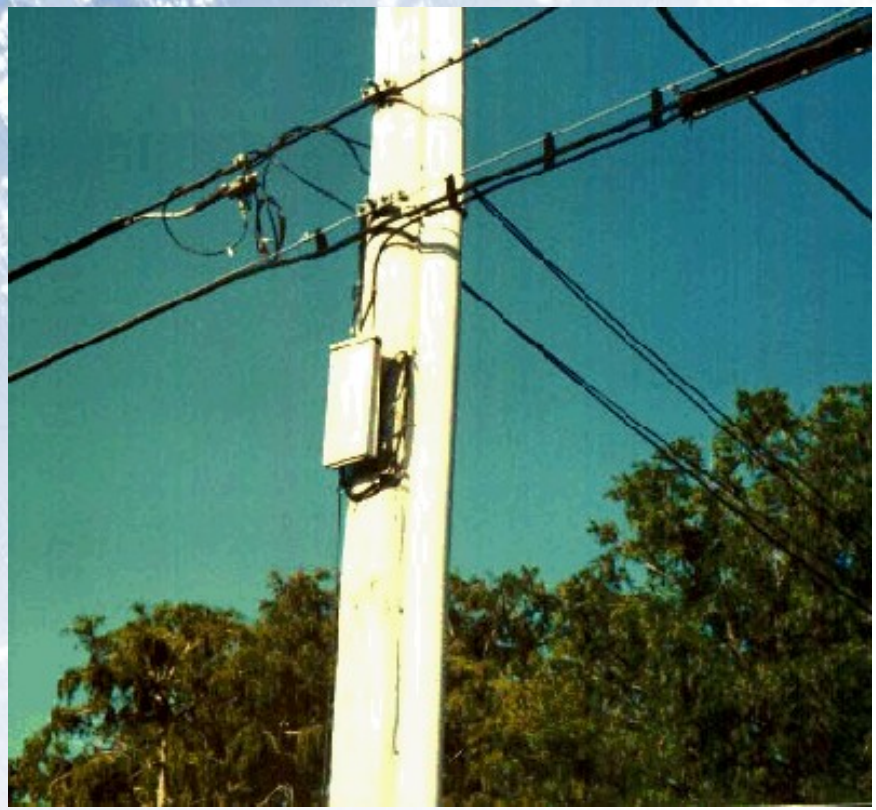
Direct Feeder Architecture

Service Wire



Aerial Service Wire connected
To a NID

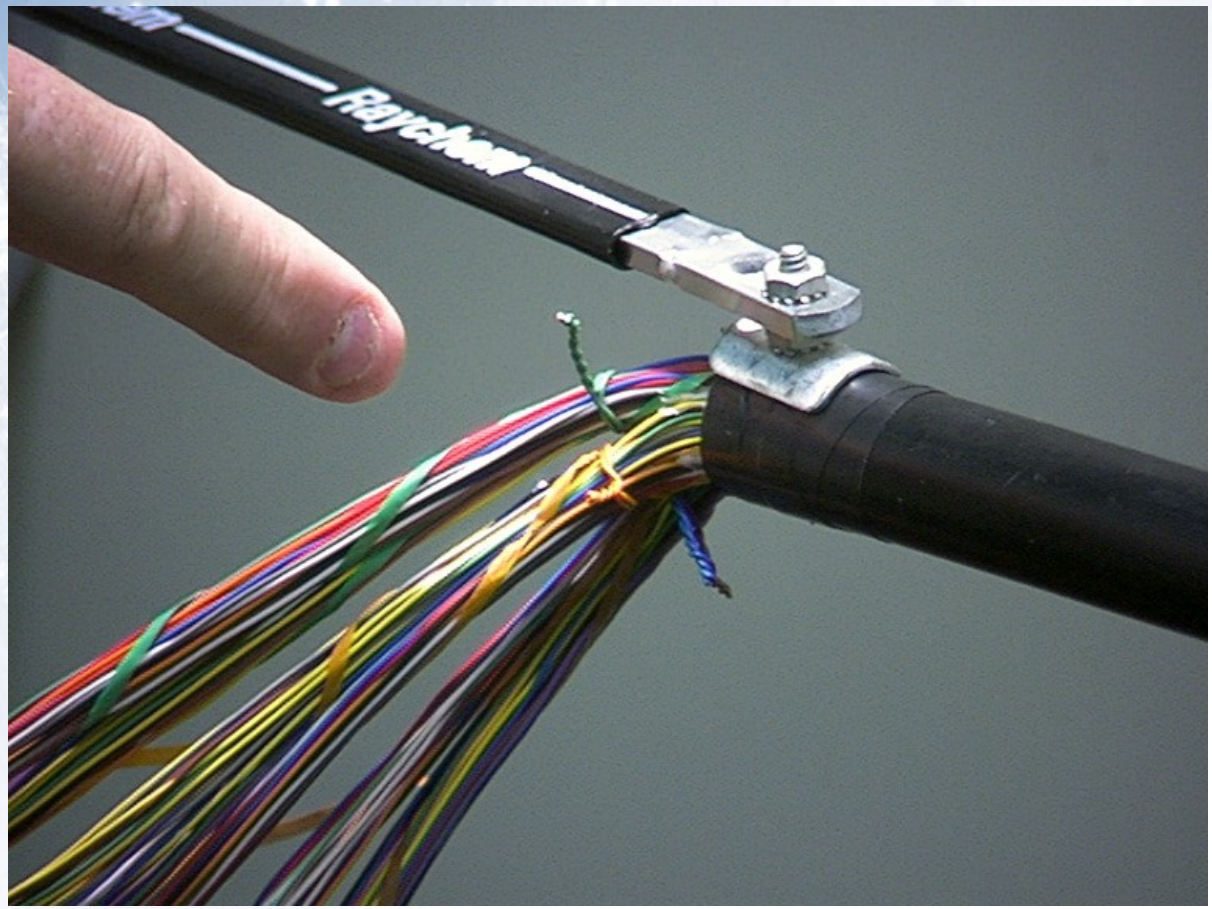
Direct Feeder Architecture



Aerial Terminal

Pedestal Terminal

Direct Feeder Architecture



Twisted Pair Cable

Direct Feeder Architecture

Central Office (CO)

III. Feeder-Distribution Interfaces: Distributed Feeder Architecture

Feeder-Distribution Interface (FDI)

FDIs provide an important function in the local loop. They serve as the interface between cables coming from the central office and cables distributed to customers.

They also provide a useful location from which to test circuits and isolate problems in the line.

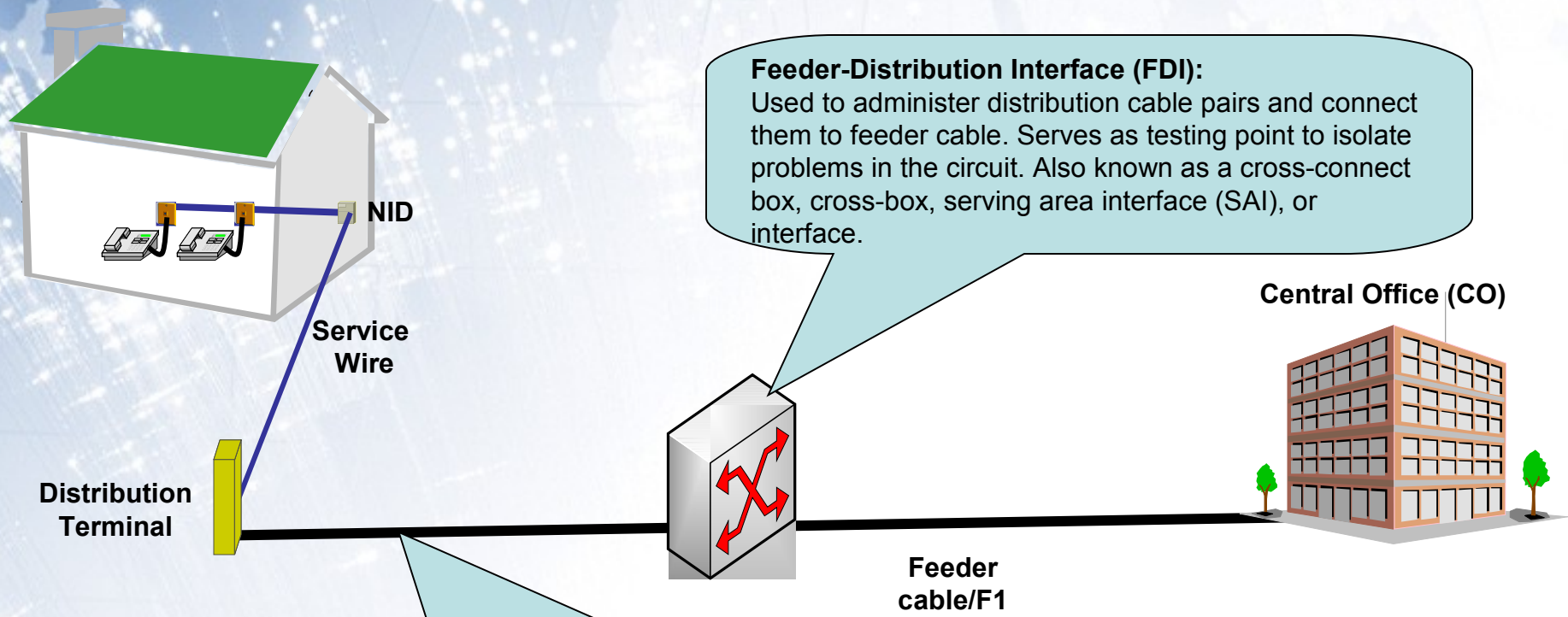
Other names for FDI include: cross-connect box, cross-box, serving area interface (SAI).

Feeder-Distribution Interface (FDI) (continued)

When an FDI is installed, the cable plant is segmented into two major components known as:

- Feeder facilities (F1)
- Distribution facilities (F2)

Distributed Feeder Architecture: Copper-Fed FDI

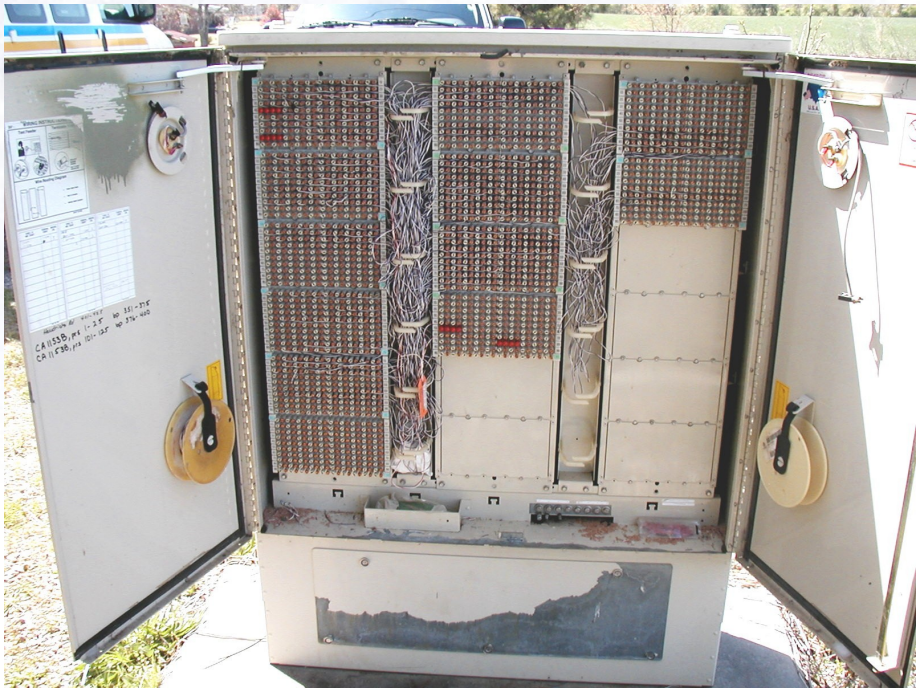


Feeder-Distribution Interface (FDI):
Used to administer distribution cable pairs and connect them to feeder cable. Serves as testing point to isolate problems in the circuit. Also known as a cross-connect box, cross-box, serving area interface (SAI), or interface.

Distribution Cable:
Used to administer distribution cable pairs and connect them to feeder cable. Separating feeder from distribution allows greater flexibility and reduced costs in equipping a central office. Also known as Facilities 2 (F2).

Distributed Feeder Architecture: Copper-Fed FDI

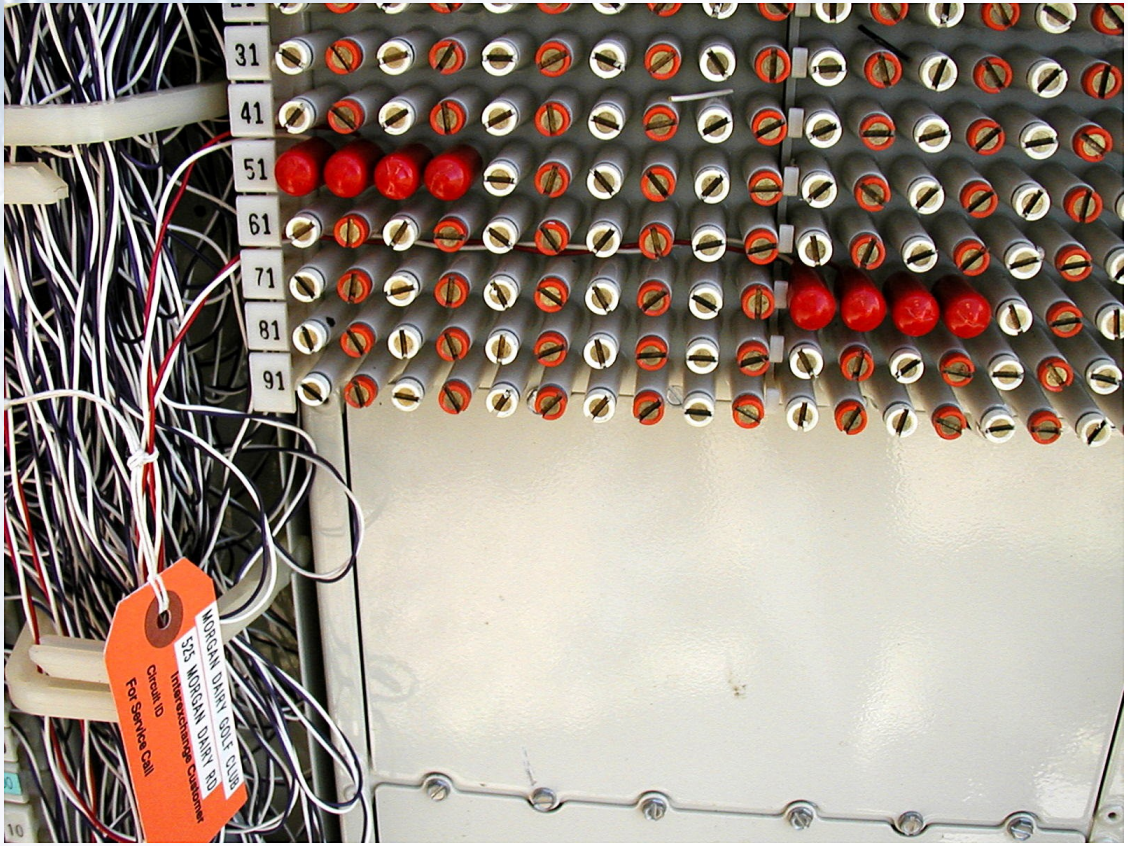
Closed View



Open View

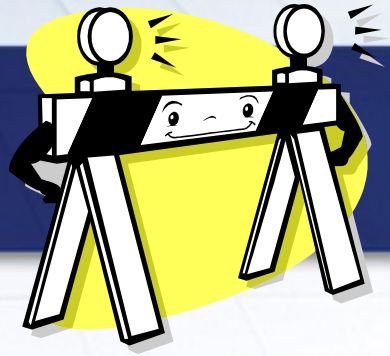
Feeder-Distribution Interface (FDI)

Distributed Feeder Architecture: Copper-Fed FDI



Feeder-Distribution Interface (FDI)
Close-up View of Binding Posts

IV. Electronic Equipment in the Local Loop



Electronic Equipment in the Local Loop

Electronic equipment in the local loop is vital in providing today's high-bandwidth services. They fall into the following categories.

- SONET Multiplexers
- Digital Loop Carrier
- DSL Access Multiplexers
- Fiber to the Curb

V. SONET Multiplexers

SONET Multiplexers

The importance of SONET multiplexers cannot be overstated. They tie together every major network element in a modern telecommunications network.

Synchronous Optical NETwork (SONET), is a technology that enables optical transport of high-bandwidth signals over long distances.

Telecom companies build SONET networks in ring topologies to create what is known as a self-healing ring (SHR).

SONET Multiplexers (continued)

The equipment nodes in these rings serve to take optical signals down to an electrical level to feed other equipment to provide customer service.

Besides POTS and voice communications, a significant part of these networks is used to interconnect enterprise LANs (Local Area Networks).

In fact, LAN interconnection services are the fastest growing driver of new telecommunications technologies.

SONET Multiplexers (continued)

Example of a SONET multiplexer equipped to deliver 28 T-1s and one T-3.

This model can transport up to 622Mbps of data and voice traffic over a SONET ring.

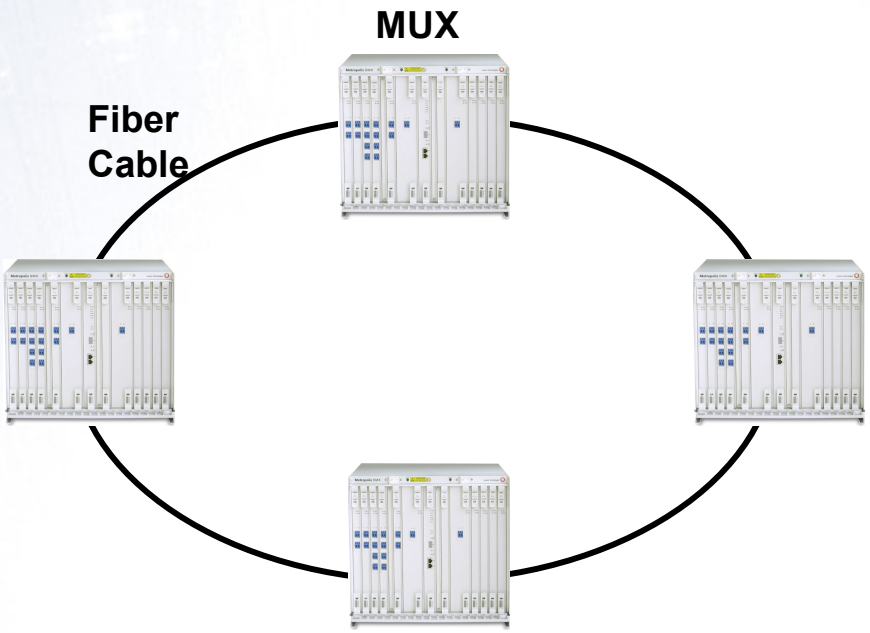
SONET Multiplexers (continued)

This next-generation multiplexer can deliver even more T-1s and T-3s for service. This model can transport up to 2.488Gbps of data and voice traffic.

SONET Multiplexers (continued)

Illustration of a 4-node SONET ring.

A multiplexer is generally referred to as a MUX.



SONET Multiplexers (continued)

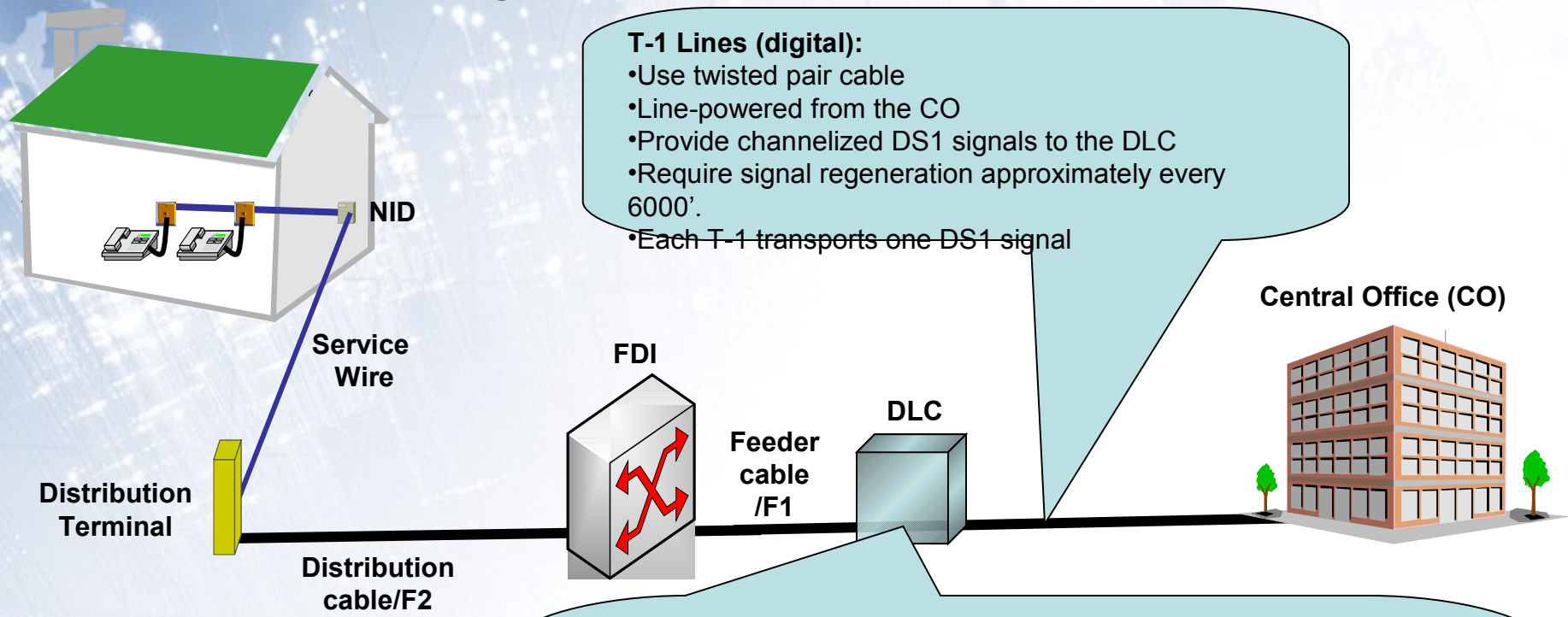
All of the subsequent electronic network elements that are presented here are supported by SONET multiplexers.

The only exception is T-1 fed Digital Loop Carrier, which is explained next.

VI. Digital Loop Carrier (DLC): Copper T-1 Feed

Digital Loop Carrier: Copper T-1 Feed

T-1 Lines (digital):
- Use twisted pair cable
- Line-powered from the CO
- Provide channelized DS1 signals to the DLC
- Require signal regeneration approximately every 6000'.
- Each T-1 transports one DS1 signal



Digital Loop Carrier (DLC):
- Performs A/D and D/A conversion of POTS
- Takes channels from the DS1 signal and converts them to DS0s for POTS
- DS1 signals can be received from a T-1 or from a fiber multiplexer
- Needs commercial power and has battery back-up
- Usually installed in private easements or inside buildings
- Installed in a cabinet, vault, hut, or building to protect the electronics

Digital Loop Carrier: Copper T-1 Feed Cabinet Enclosures

DLC cabinet with door open

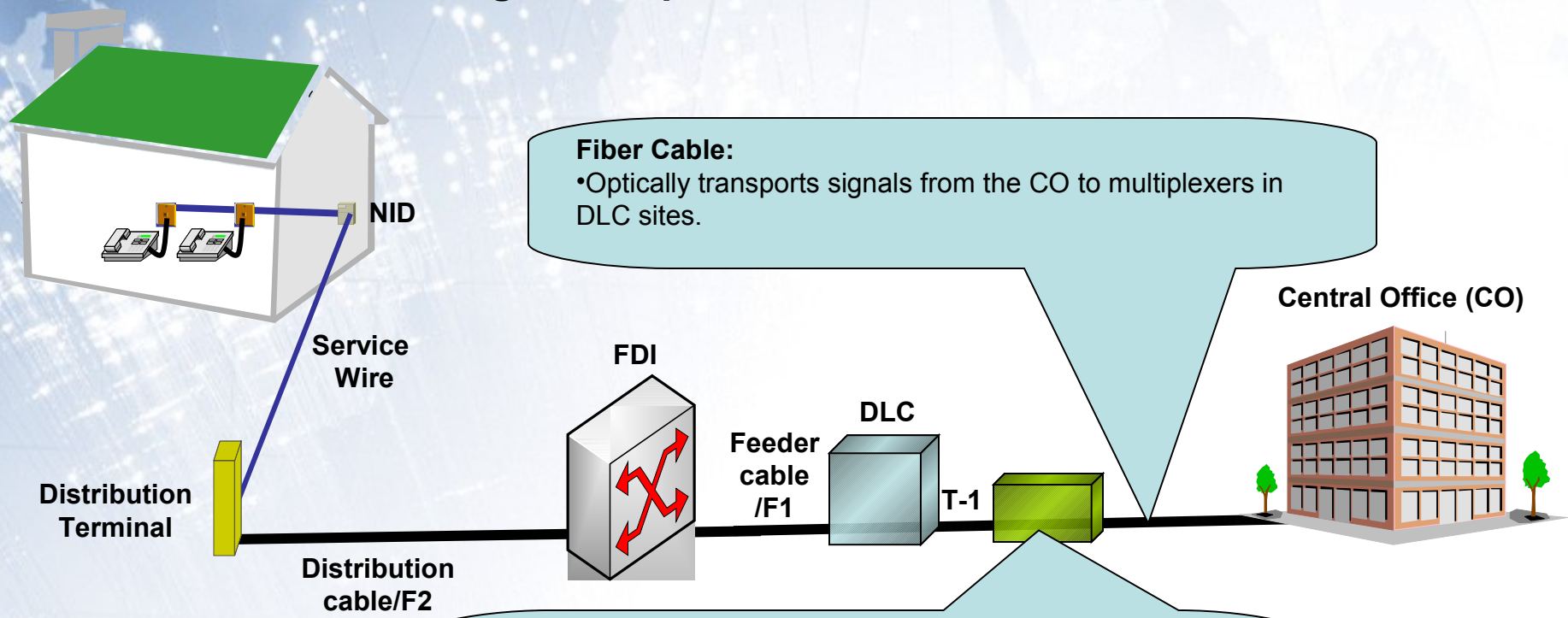
Digital Loop Carrier: Copper T-1 Feed
Other Enclosures

DLC in electronics hut

DLC in Controlled Environment Vault (CEV)

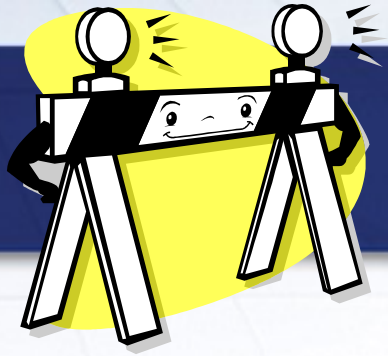
VII. Digital Loop Carrier: SONET Mux Feed

Digital Loop Carrier: Fiber Mux Feed



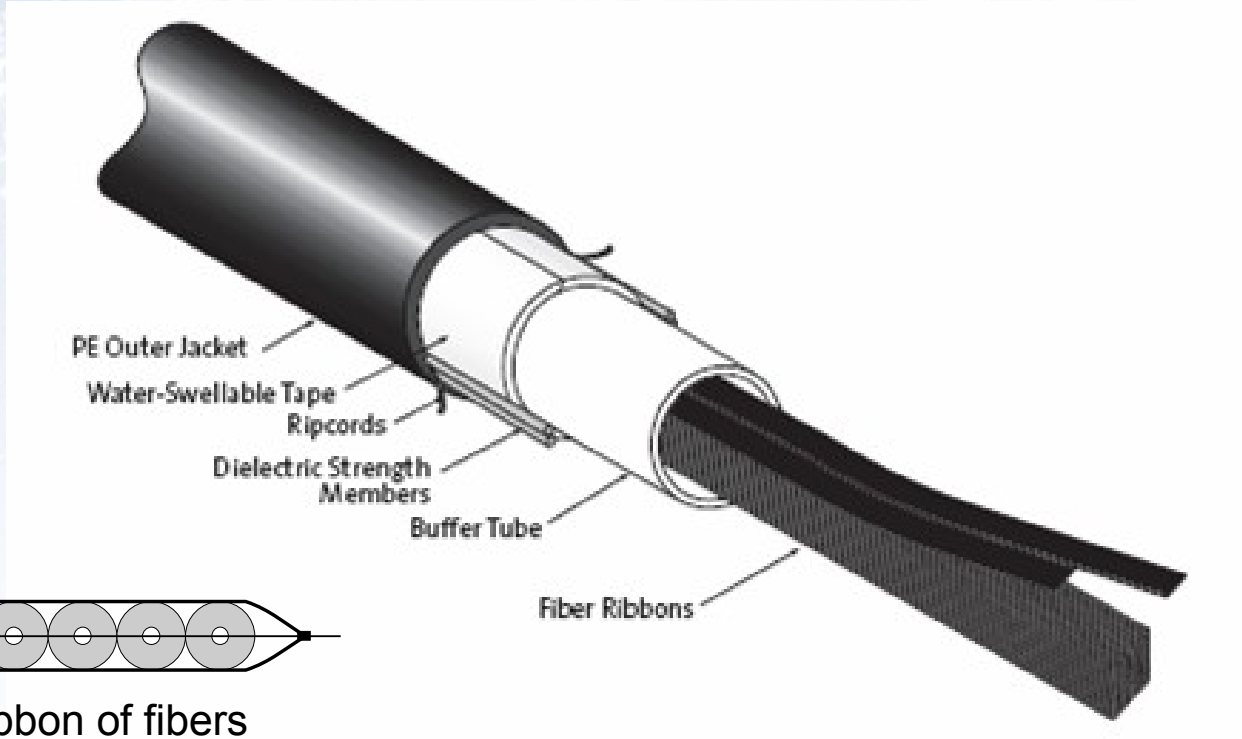
Fiber Cable:
- Optically transports signals from the CO to multiplexers in DLC sites.

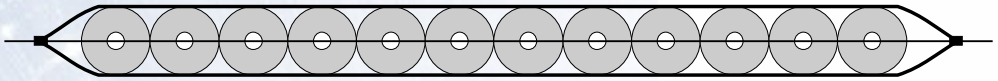
SONET Multiplexer:
- Receives optical signals carrying channelized DS1s from the CO and converts each DS1 to a T-1 to feed the DLC equipment
- Can also receive optical signals carrying DS3s for service or for DSL Access Multiplexers
- Frequently referred to as a MUX



Digital Loop Carrier: Fiber Mux Feed

Fiber cable sheath with ribbons of fibers to connect the fiber multiplexer to the central office

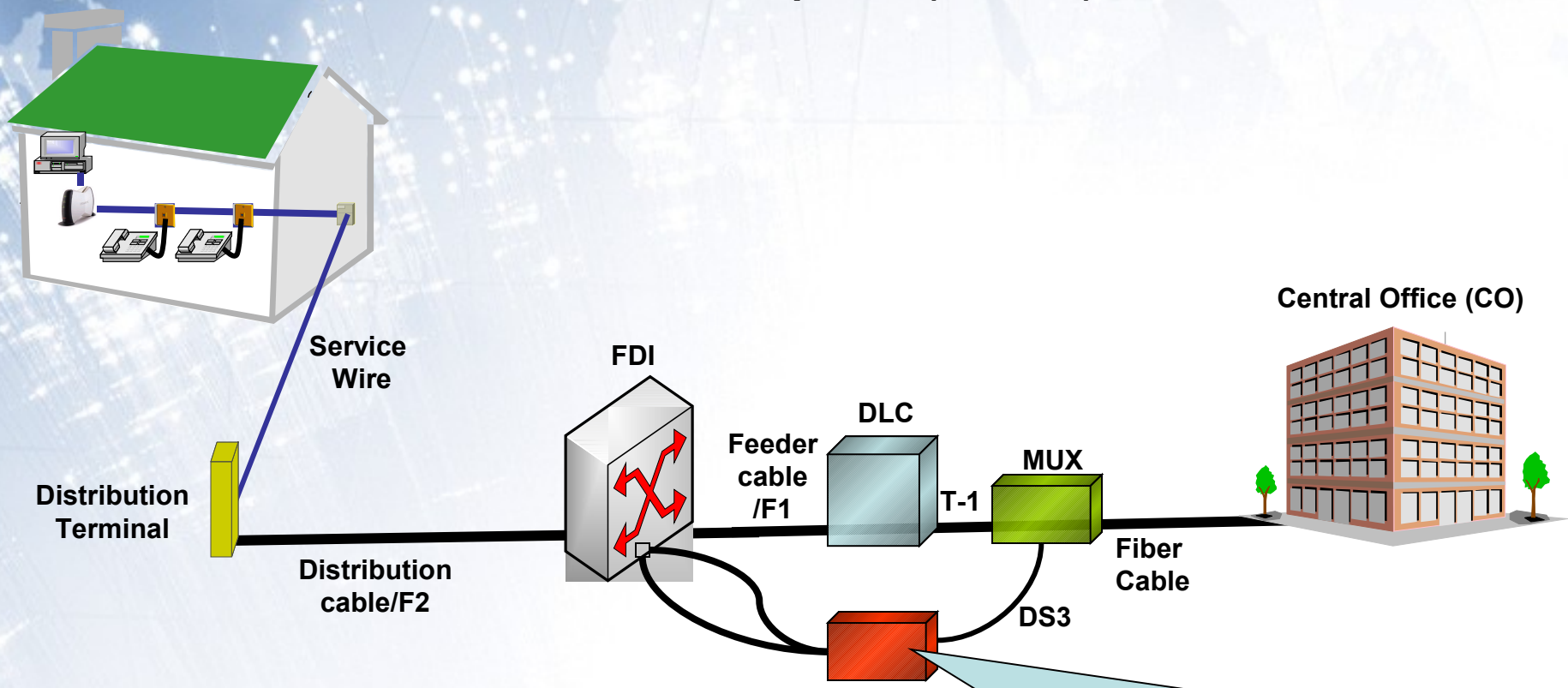




Cross-sectional view of one ribbon of fibers

VIII. DSL Access Multiplexer (DSLAM)

DSL Access Multiplexer (DSLAM)



DSL Access Multiplexer (DSLAM):

- Receives electrical DS3 from the CO via a multiplexer
- Takes Feeder pairs from FDI and adds DSL channels to them
- Referred to as a DSLAM

DSL Access Multiplexer (DSLAM)

DSLAM mounted on a rack

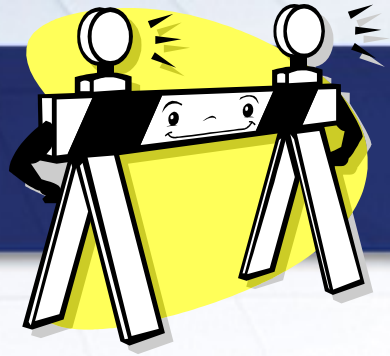
IX. Fiber to the Curb (FTTC)

Fiber-to-the-Curb (FTTC)

FTTC is a new architecture that has been deployed for the last several years.

It consists of placing fiber cables in neighborhoods and businesses and connecting electronics equipment at the edge of the customer premises.

FTTC also requires specialized DLC equipment that can support optical transmission of POTS lines.



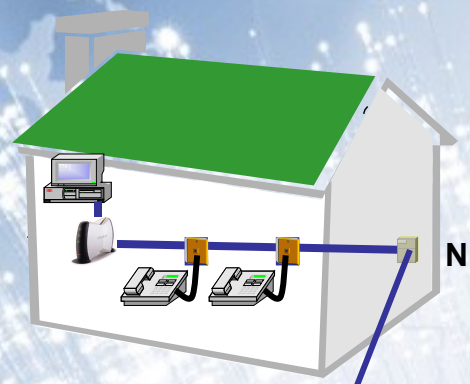
Fiber-to-the-Curb (FTTC) (continued)

FTTC allows optimal quality of services and it enables higher-bandwidth services to be provided.

The term FTTC stems from the fact that when deployed in neighborhoods, the electronics terminal -known as an optical network unit (ONU)- sits near the street curb.

This is a different architecture from fiber-to-the-premises (FTTP), to be explained later in this presentation.

Fiber To The Curb

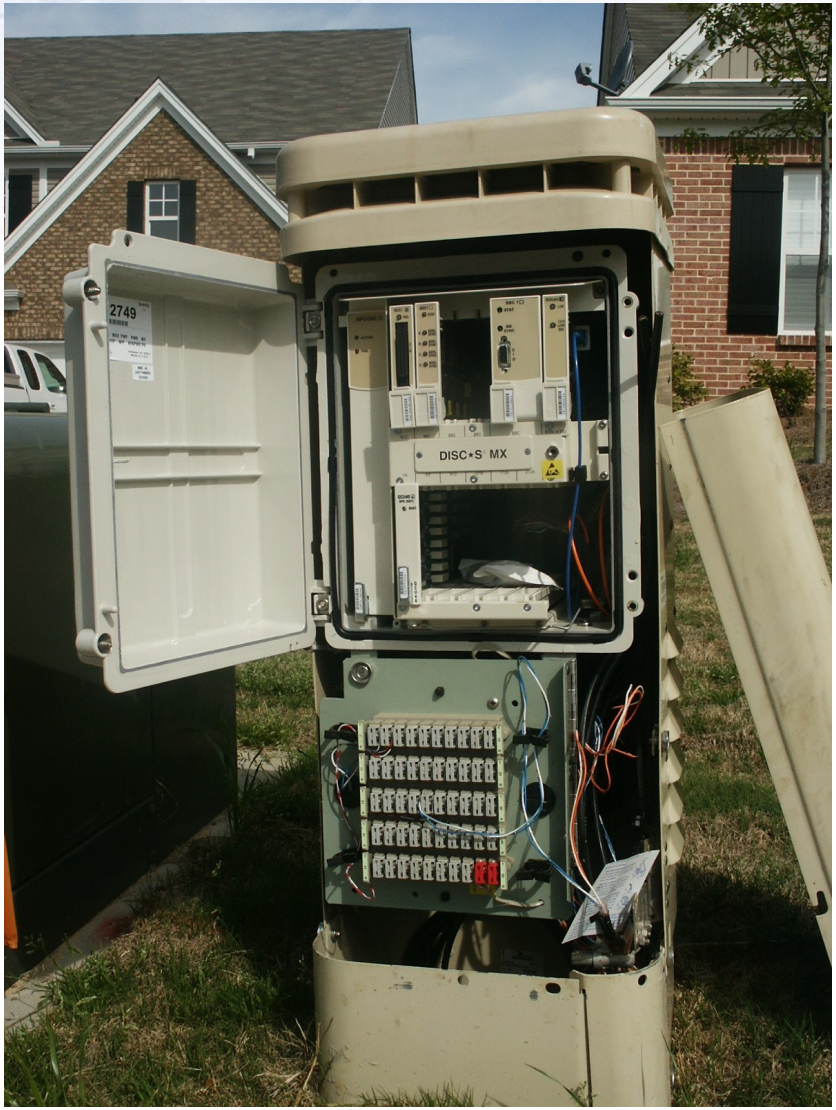


Distribution Fiber:
- FTTC requires placing fiber as distribution cable
- Twisted copper pairs must be included alongside or within the fiber cable sheath to provide electrical power to the ONUs

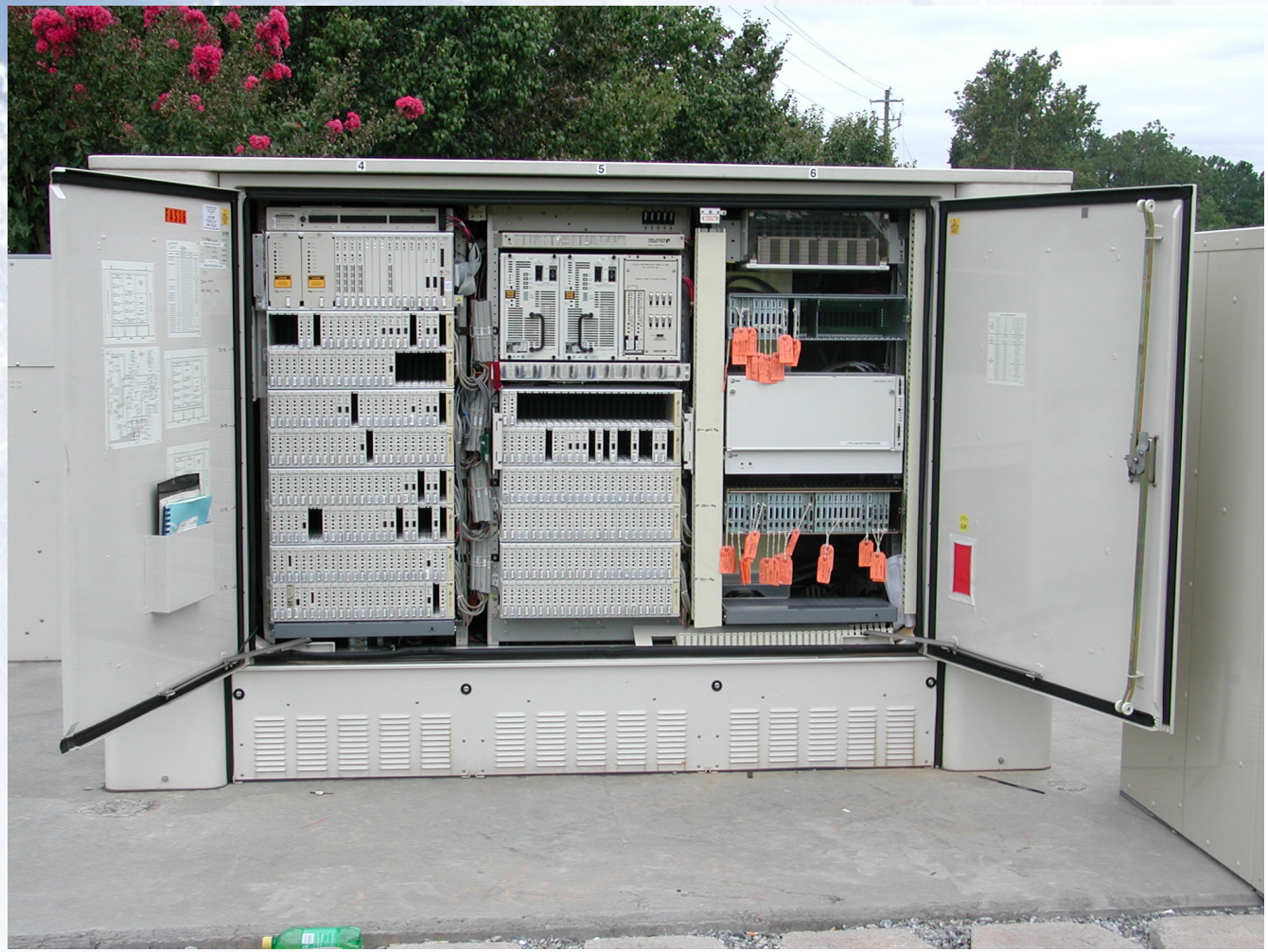
Optical Network Unit (ONU):
- Consists of a metallic, weatherproof enclosure equipped with electronics
- Distribution fiber cable is looped into the enclosure and one fiber strand is connected to the optical line interface
- ONUs remain on the edge of the street, thus the term fiber-to-the-curb

Fiber To The Curb

Optical Network Unit (ONU)



Fiber To The Curb



DLC cabinet for FTTC

X. Fiber to the Premises (FTTP) & Fiber to the Home (FTTH)

Fiber-to-the-Premises (FTTP)

FTTP is another new architecture that has been deployed for the last few years.

It consists of placing fiber cables in neighborhoods and businesses and connecting electronics equipment at the edge of the customer premises.

It differs from FTTC in that the electronics terminal resides inside the customer's premises.

Fiber-to-the-Premises (FTTP) (continued)

Placing the electronics terminal inside the customer's premises relies on the customer's power feed to the electronics.

For this reason, a rechargeable battery backup unit connected to an AC outlet needs to be installed inside the customer premises.

XI. Wireless Options:
Cellular Systems

Cellular Systems

Cellular systems are an efficient and popular telecommunications technology.

The convenience of a cellular telephone has overridden the lowered sound quality and connection reliability.

There are several cellular technologies that have been deployed in the U.S. alone.

Cellular Systems (continued)

The latest cellular system technologies deployed in the U.S. include:

CDMA - Code Division Multiple Access

GSM - Global System for Mobile

- GPRS & EDGE are subsets of GSM

iDEN - Integrated Digital Enhanced Network

UMTS - Universal Mobile Telecommunications System

- CDMA2000 is a subset of UMTS

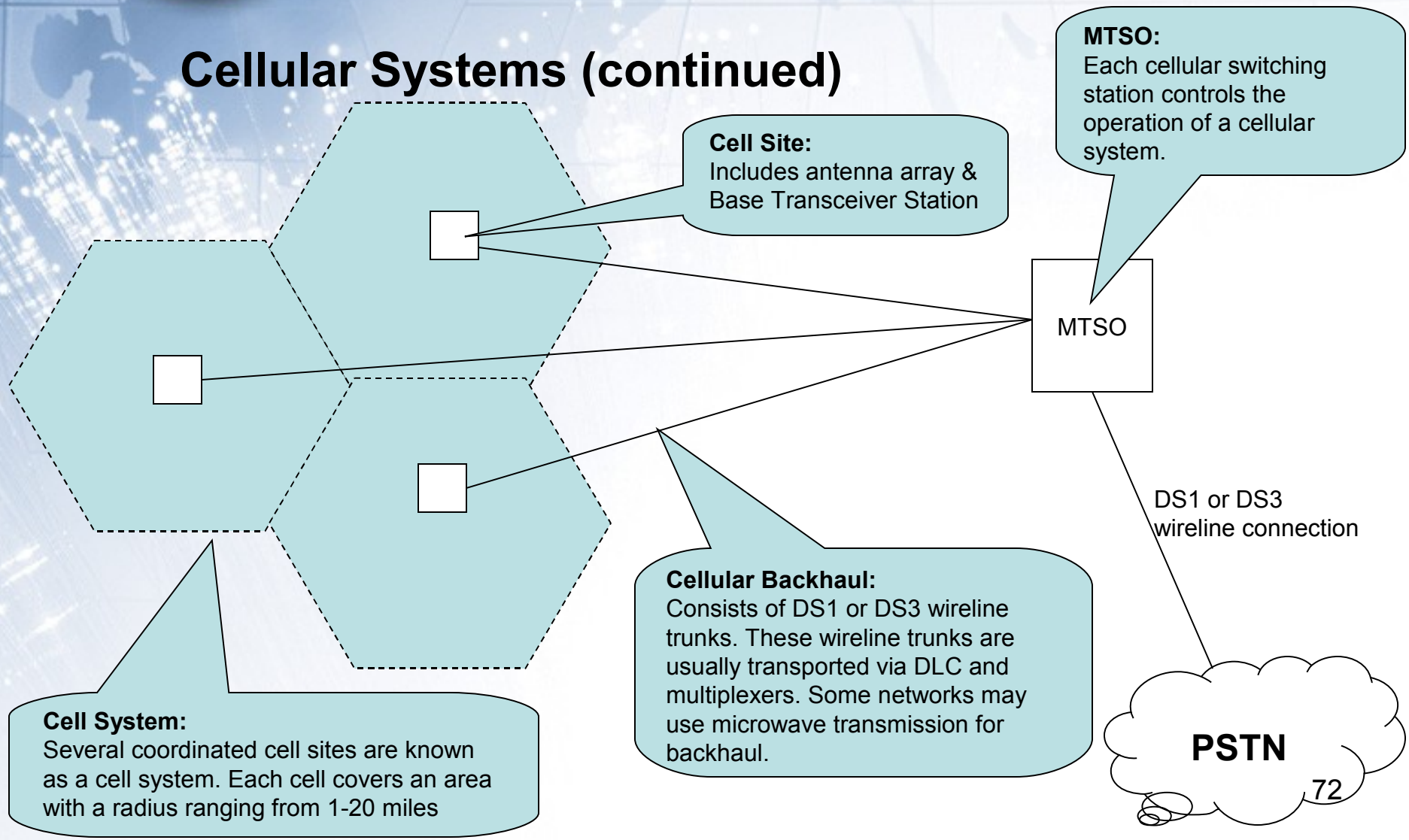
Cellular Systems (continued)

Regardless of the wireless technology used by the carrier, the physical architectures remain relatively the same.

A cellular system consists of:

- Antenna arrays
- Base Transceiver Stations (BTS)
- Mobile Telephone Switching Office (MTSO)
- Backhaul connectivity
- Commercial power source

Cellular Systems (continued)



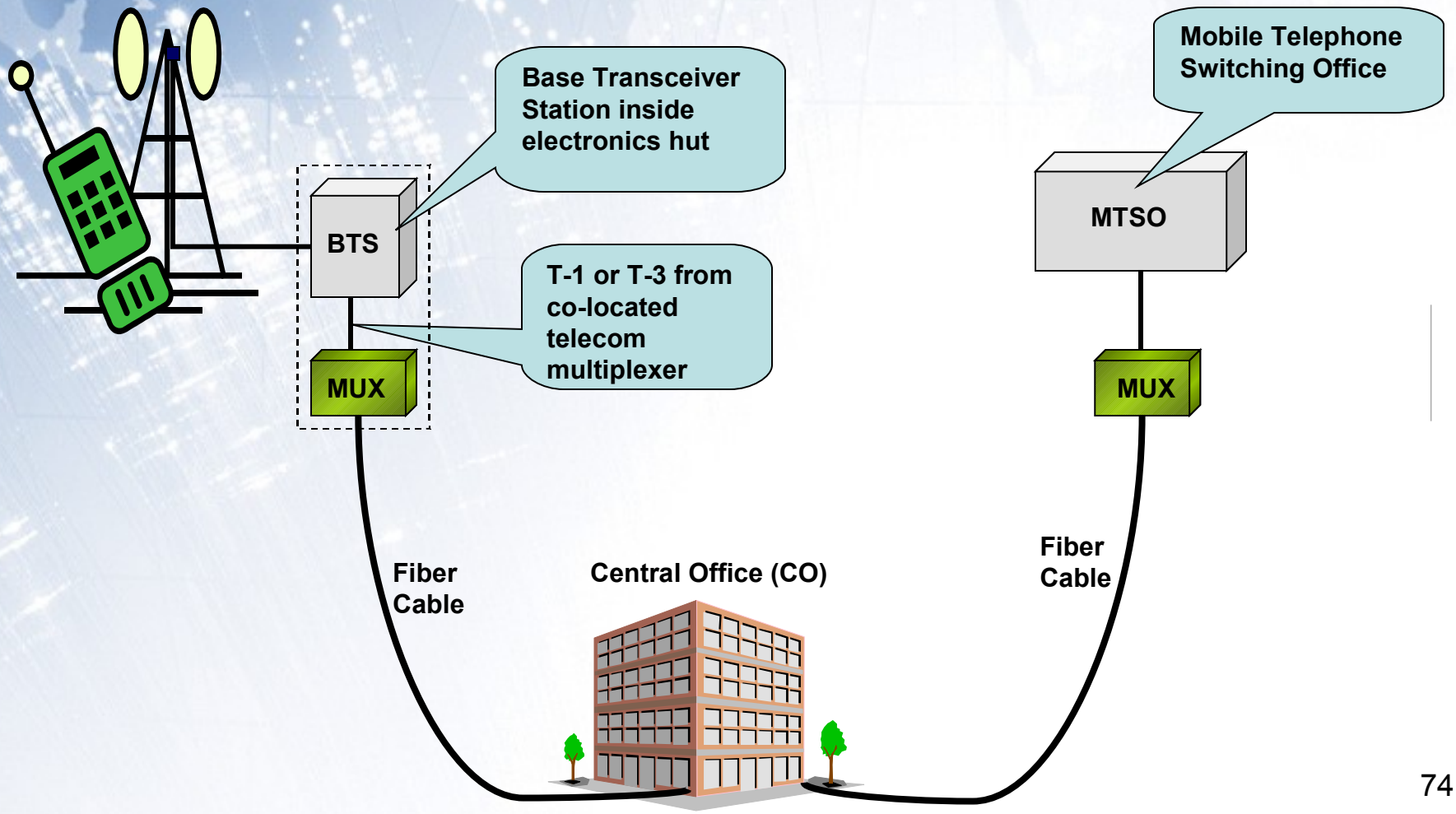
Cellular Systems (continued)

Main take-away: Even though the connection from the phone set to the antenna is wireless…

… the antenna's connection back to a switch is usually carried by wireline telecom equipment…

…and commercial power is still needed.

Cellular Tower Connections



XII. Wireless Options: WiMAX

WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is a technology that enables wireless transmission of digital broadband signals.

Effectively, it is supposed to be a replacement for wireline DSL and cable modem.

It may also be used for wireless backhaul.

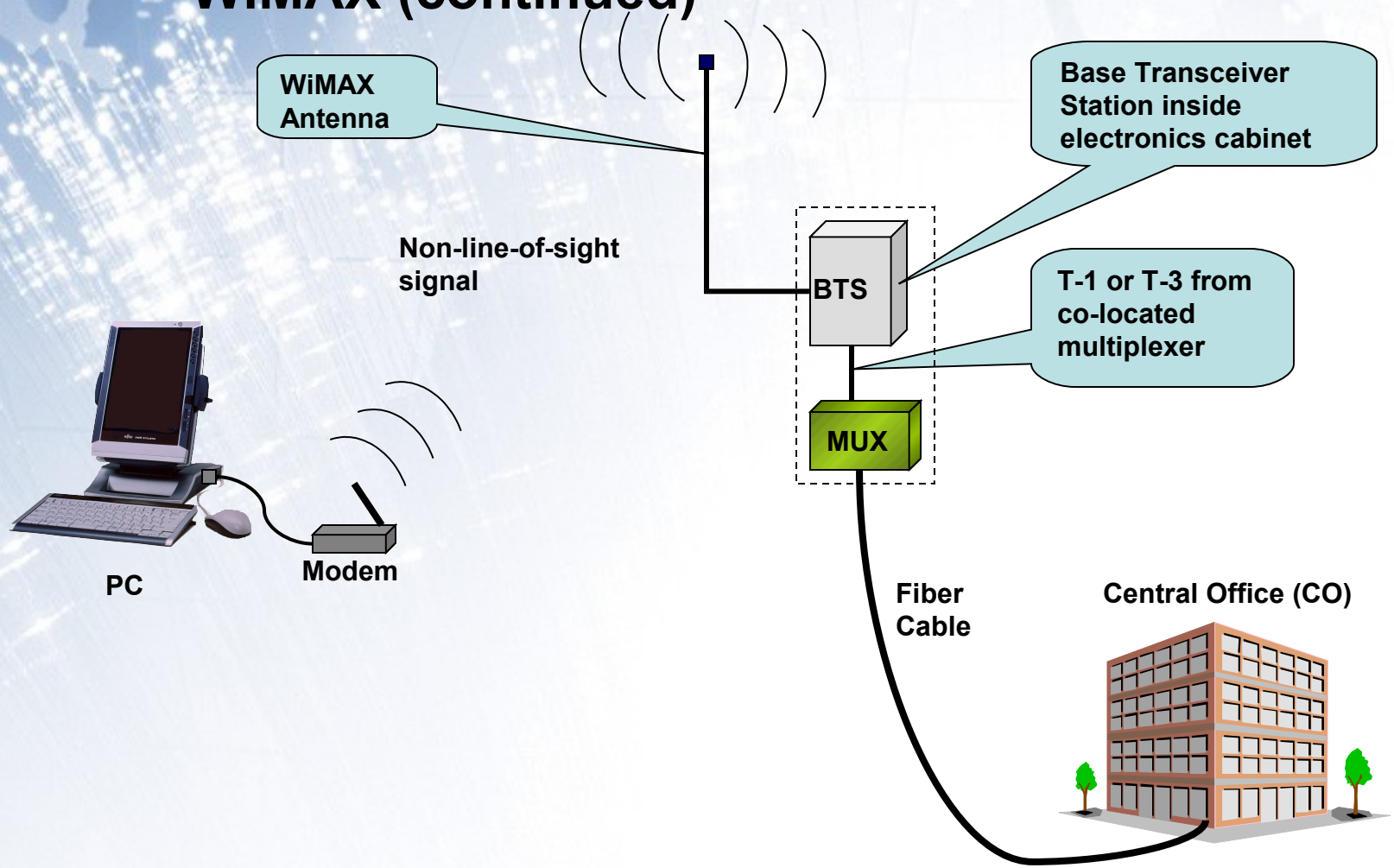
WiMAX (continued)

Two forms of WiMAX are being developed:
Fixed WiMAX – standard IEEE 802.16d
Mobile WiMAX – standard IEEE 802.16e

Most immediate practical applications for WiMAX are:

- backhauling traffic from cellular and WiFi base stations to a central office
- replacement of enterprise T-1 circuits
- alternative to DSL and cable modem in rural or developing regions

WiMAX (continued)



WiMAX (continued)

WiMAX is still a new technology and has not reached a high rate of adoption.

Analysts predict that late 2006 will see more WiMAX carrier level devices available in the market.

Currently there are other products that use the same concept, but with proprietary standards. These are known as *pre-WiMAX* technologies.

WiMAX (continued)

Main take-away: WiMAX and pre-WiMAX architectures still require wireline transport to a central office and commercial power.

XIII. Wireless Options: WiFi

WiFi

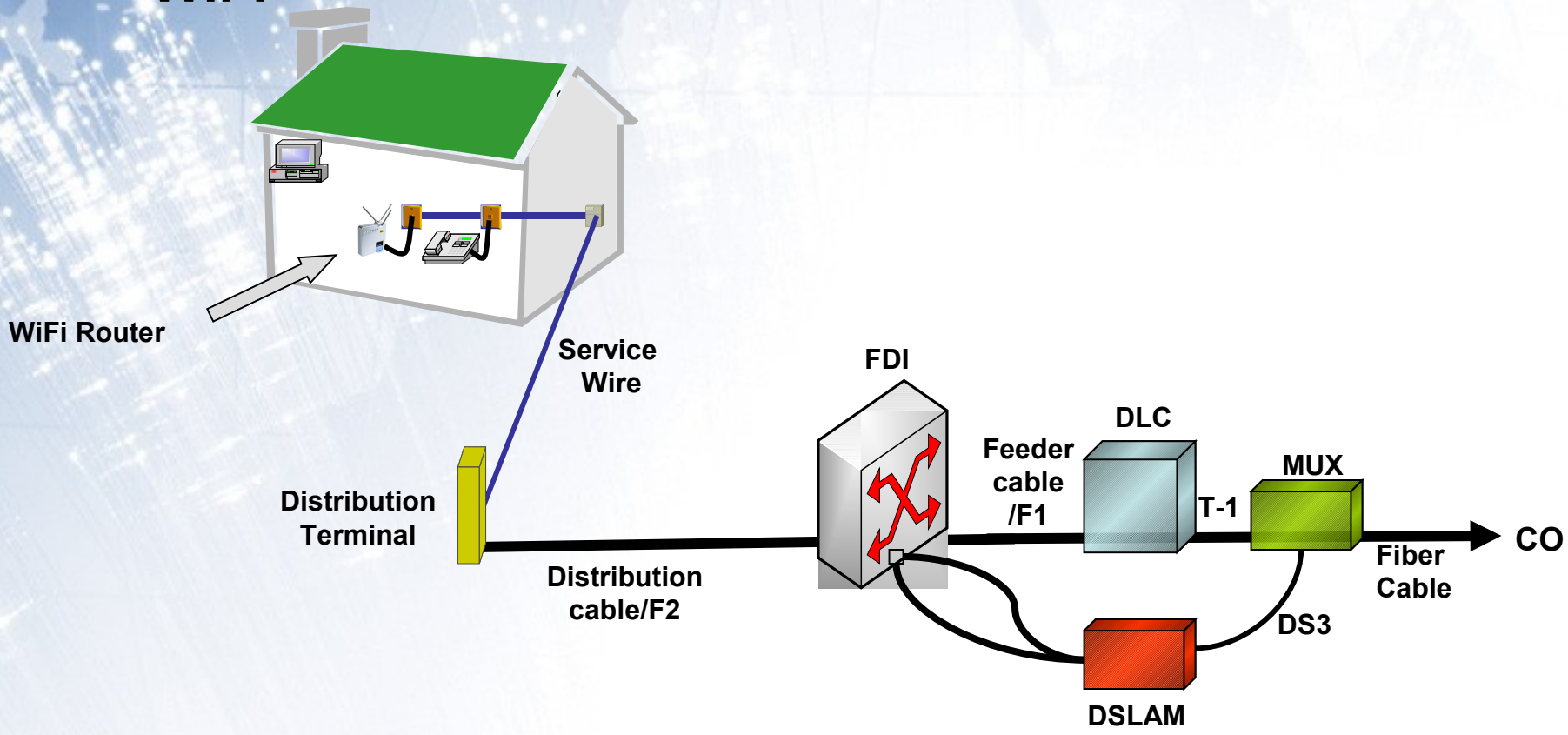
Wireless Fidelity (WiFi):

- is IEEE 802.11b & 802.11g standards for fixed broadband wireless access with short reach
- reach is ~ 300’ depending on obstructions

The WiFi signal is transmitted to and from a base station known as an access point

- uses the unlicensed 2.4GHz band radio frequency (cordless phones and microwave ovens use this same band)

WiFi


WiFi Router
Service Wire
FDI
DLC
Feeder cable /F1
MUX
T-1
CO
Fiber Cable
Distribution Terminal
Distribution cable/F2
DS3
DSLAM

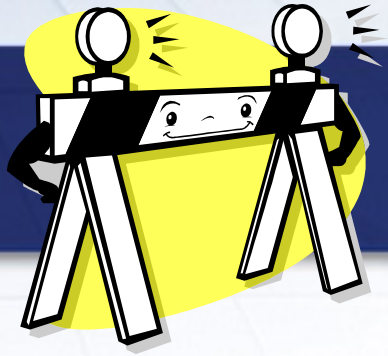
WiFi (continued)

Allows users to gain wireless connectivity to a router – the access point. The router in turn can have a high-speed connection to an Internet Service Provider.

WiFi works with:

- Laptops
- PDAs
- any WiFi-enabled devices

A wireless Local Area Network (WLAN) is also known as a hotspot and uses WiFi technology.



WiFi (continued)

There are many wireless routers in the market. Below i are two pictures of typical designs.

WiFi (continued)

In short, WiFi merely replaces the Category 5e cabling from a laptop/PC to a router.

The connection from the router to the central office is a wireline connection, and the router requires commercial power.

XIV. Catastrophic Events & The Local Loop

"Normal" Disasters

- Long-term loss of commercial power
- Flood & wind damage
- Damage or disability to road infrastructure

Katrina

- Long-term loss of commercial power
- Flood & wind damage
- Damage & disability to road infrastructure
- Civil disturbances
- Corrosive toxins in flood waters
- Dislocation of workforce

Status of BellSouth's Network on 9/1/2005

- 53 SONET rings were severed in multiple points
- 22 COs were either out of service or evacuated
- 38 CO switches were isolated from the SS7 network & unable to process inter-office calls
- 7 COs were on batteries, 151 on generators, some of which could not be accessed for refueling

Summary of Damages to BellSouth's Network

– COs damaged or destroyed	33
– Poles damaged	24,982
– Cable spans down	66,465
– Downed service wires	141,182
– FDIs damaged	750+
– DLC sites destroyed	34
– Damaged distribution terminals	33,000
– Feeder cable destroyed	1.9M sheath feet
– Sludge removed from manholes	830 tons

Damaged & Destroyed Central Offices

Damaged & Destroyed Central Offices

XV. Recovery Efforts

Recovery Efforts

Equipment Shipped

- 2,334 Truckloads of Network Equipment

Generators Deployed

- 1,044 Generators deployed multiple times
- Total of 333 truckloads of generators moved

Fuel Distributed

- 1.5M gallons of diesel fuel for generators and vehicles
- 1M gallons of unleaded gas for vehicles
- 43 Refueling Tankers, 27 above ground storage tanks
- 949 Additional Vehicles Provided

Recovery Efforts (continued)

Temporary Telephony

- Deployed portable DLC Equipment
  - DLC & MUX in cabinet; powered by generator; backhaul is microwave transmission (known as “SLC on Wheels”)
- Wireless POTS
  - Works like a local POTS phone, but connects to the cellular network
  - Phone is AC powered
  - Allows customers to forward their regular phone number to the wireless POTS phone to facilitate communications with relatives & friends, insurance companies, etc.
  - Requires a functioning cell system

Recovery Efforts (continued)

Temporary Internet Access

- Deployed pre-WiMAX technology to serve returning homeowners served by damaged wireline plant
  - Wireless Broadband

Temporary Restoration of Links to Cell Sites

- Deployed optical T-1s

Recovery Efforts (continued)

Business Processes

Set up teams throughout the region to handle millions of transactions:

- Billing credits
- New connections
- Disconnections
- Employee assistance
- Approval of temporary technologies
- Many other operations and administration functions that are critical to operations

XVI. References & Glossary

Resources to Learn More About Telecommunications

www.fcc.gov/cgb/

www.wikipedia.com

www.howstuffworks.com

www.itu.int

www.iec.org

GLOSSARY OF ACRONYMS

A/D – Analog-to-Digital conversion
D/A – Digital-to-Analog conversion
DLC – Digital Line Carrier
DS0 – Digital Signal level 0
DS1 – Digital Signal level 1
DSL – Digital Subscriber Line
DSLAM – DSL Access Multiplexer
FDI – Feeder-Distribution Interface
FTTC – Fiber to the curb
FTTH – Fiber to the home
FTTP – Fiber to the premises
LAN – Local Area Network
MUX - Multiplexer
NID – Network Interface Device
POTS – Plain Old Telephone Service
PSAP – Public Service Answering Point (911 Center)
PSTN – Public Switched Telephone Network
SAI – Serving Area Interface
WiFi – Wireless Fidelity
WiMAX – Worldwide interoperability for Microwave Access