Bell Labs Analysis for BT

End to End – Next Generation Voice Network Architectures

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Outline

1. Objectives, Overview and Approach

2. Review of Potential Voice Solutions & Next-Gen Architectures
    -   Managed Voice Solutions
    -   Unmanaged Voice Solutions

3. Examples of Service Providers Offering Next-Gen Voice Technologies

4. Key Observations
    -   Critical Elements of the Cost Model
    -   Bandwidth Limitations and Economics of Copper Access Networks
    -   Evolution/Expansion of the Core Network
    -   Differentiating Between Managed and Unmanaged Voice Service
    -   The User Experience and its Impact on Each Scenario
    -   Categorizing the Different Voice Architectures

5. Conclusions

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Objectives

- Define a set of feasible architectural alternatives that illustrate an extensive cross-section of how service providers can provide voice communication services as the PSTN network is phased out

- Provide an analysis of the alternatives, defining:
  - Qualitative pros/cons for each of the solutions
  - Develop general observations about the set of solutions as a whole and key elements that are needed in a next-generation voice network cost model

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Overview and Approach

- A joint workshop was held between BT and Bell Labs to discuss feasible alternatives for providing voice service over a next-generation network

- During this workshop:
  - A list of 16 feasible solutions initially provided by BT was jointly reviewed and expanded to 22
    - It was further expanded to 37 due to the fiber termination point being separated from the voice solution
  - These solutions are generic and "telco" centric
    - The technologies included are not representative of BT or any other operator
    - E.g., cable (MSO) and PLT solutions are not included
  - The voice solutions were categorized as either:
    - Managed – cases where the service quality can be ensured over the entire end to end path, or
    - Unmanaged – where call quality cannot be assured over one or more of the path legs

- The resulting 37 solutions are evaluated by Bell Labs in this package:
  - Identifying qualitative pros/cons for each of the alternatives
  - Providing examples of how service providers are deploying the various technologies

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NGN Voice Architecture

Representative NGN Voice Architecture
Diagram

The comprehensive architecture diagram shows a variety of feasible alternatives for fixed voice services over a next generation network. It includes

- 17 different access architectures for managed voice services, and
- 5 different access architectures for unmanaged voice

The list is subsequently expanded to address the different cases of fiber terminating at the LE, the cabinet or the distribution point

Note: The network diagrams used in this deck are based on the representation initially provided by BT

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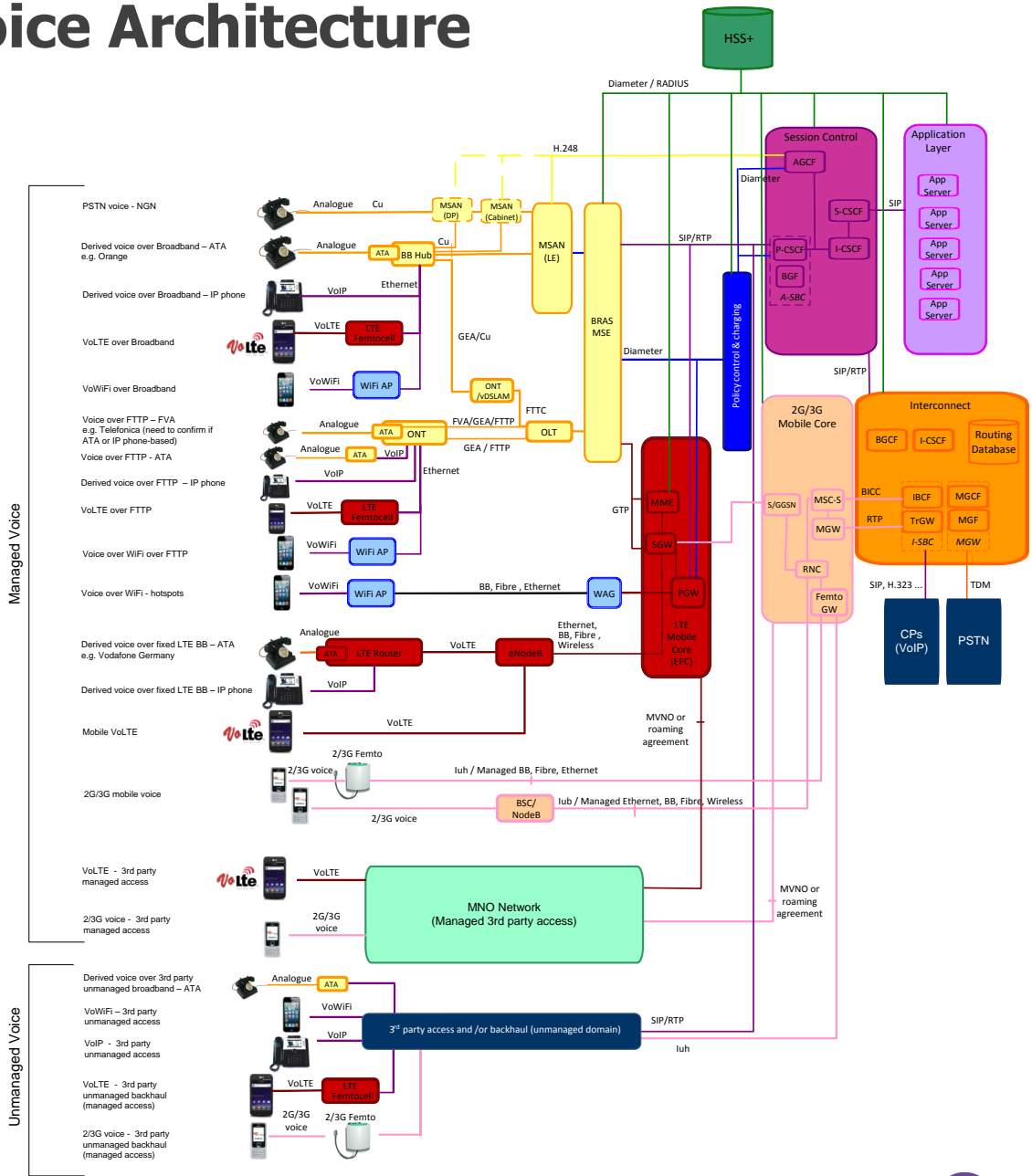
Voice Solutions

- The 37 solutions presented in the following slides provide a diverse representation of architectures possible to provide voice service as a replacement for a TDM based PSTN service.

- The architectures illustrated are chosen from a legacy Telecommunications Service Provider to residential/SMB point of view.
  - Solutions such as coaxial cable, power lines and satellite are not included.
  - Larger scale business terminations, such as Gigabit Ethernet are not included either.

- It should be noted that the technology selections, particularly in the core/control network are not exhaustive. For instance, many solutions illustrating an IMS core for call control can also be supported with a VoIP softswitch (or vice-versa).

- Despite the relatively high number of architectures presented, the intent is to illustrate the possible range of access/core technologies and not an exhaustive set of combinations.

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Summary of Managed Voice Solutions

	Voice Solution	Fiber Termination		Voice Solution	Fiber Termination
1	POTS over Cu	LE	17	VoWi-Fi*	FTTP
2	POTS over Cu	Cabinet	18	2G/3G (Sm. Cell)	LE
3	POTS over Cu	DP	19	2G/3G (Sm. Cell)	Cabinet
4	VoBB/ATA	LE (xDSL)	20	2G/3G (Sm. Cell)	DP
5	VoBB/ATA	Cab. (xDSL)	21	2G/3G (Sm. Cell)	FTTP
6	VoBB/ATA	DP (xDSL)	22	2G/3G	N/A – Mobile
7	VoIP CPE	LE (xDSL)	23	2G/3G	3rd Party – MNO
8	VoIP CPE	Cab. (xDSL)	24	VoLTE (Sm. Cell)	LE
9	VoIP CPE	DP (xDSL)	25	VoLTE (Sm. Cell)	Cabinet
10	VoWi-Fi*	LE (xDSL)	26	VoLTE (Sm. Cell)	DP
11	VoWi-Fi*	Cab. (xDSL)	27	VoLTE (Sm. Cell)	FTTP
12	VoWi-Fi*	DP (xDSL)	28	POTS over VoLTE	N/A – LTE
13	POTS over Fibre	FTTP	29	VoIP over LTE	N/A – LTE
14	VoBB/ATA	FTTP	30	VoLTE	N/A – LTE
15	VoBB, sep. ATA	FTTP	31	VoLTE	3rd Party - MNO
16	VoIP CPE	FTTP			

* - Note: While the air interface for Wi-Fi cannot be managed to ensure voice quality, the VoWiFi solutions over a private Wi-Fi network are considered to be managed voice. It is assumed that the network owner can perform de facto management by eliminating other applications while performing voice calls.

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Summary of Unmanaged Voice Solutions

	Voice Solution	Fiber Termination
32	VoWi-Fi	Public AP
33	OTT Voice over IP	3rd Party / N/A
34	VoIP	3rd Party / N/A
35	VoWi-Fi	3rd Party / N/A
36	VoLTE (Sm. Cell)	3rd Party / N/A
37	2G/3G (Sm. Cell)	3rd Party / N/A

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Voice Solution 1 – POTS Emulation over Analog Loops/Fiber at the LE
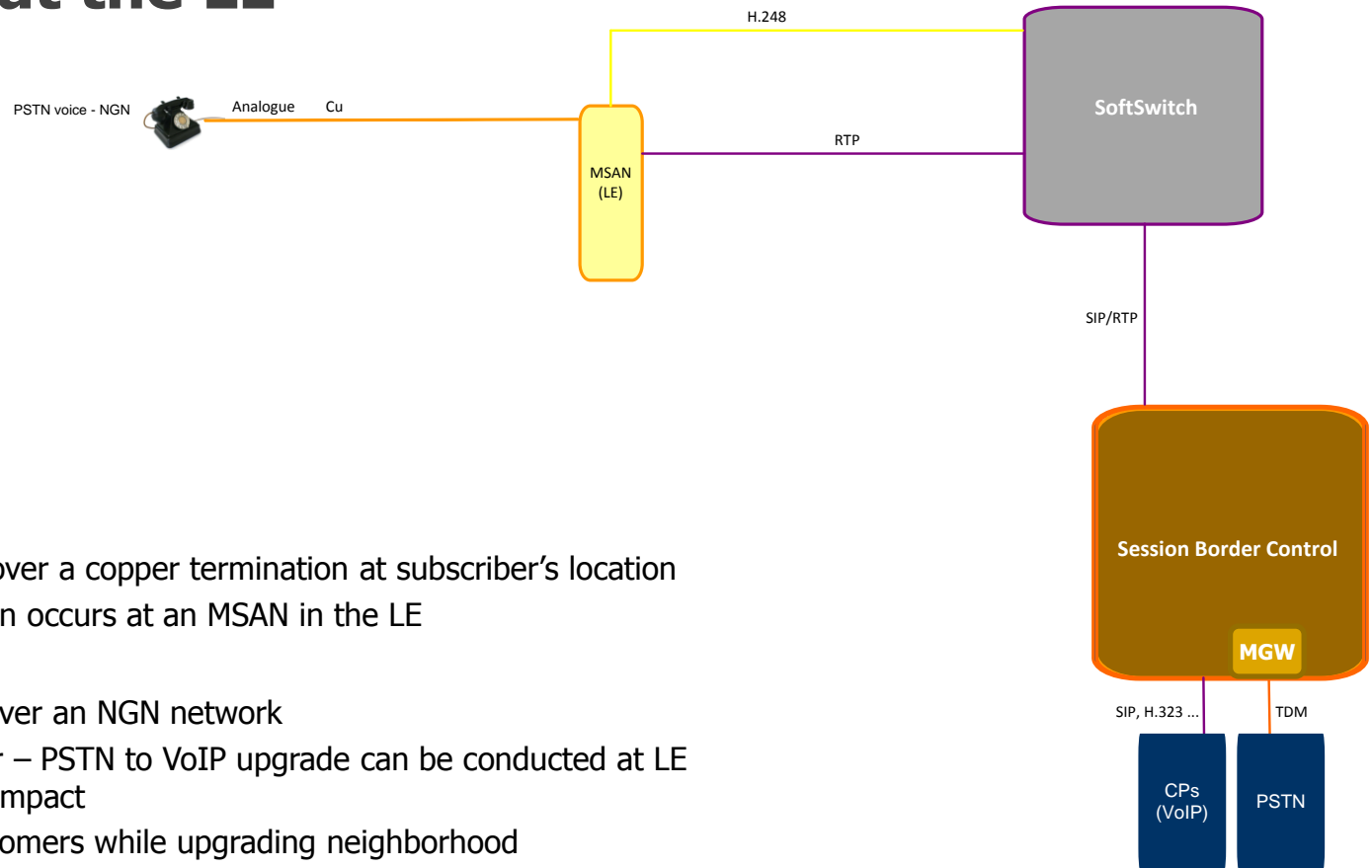
Description:

- POTS voice is emulated over a copper termination at subscriber's location
- Analog to VoIP conversion occurs at an MSAN in the LE

Pros:

- Allows POTS emulation over an NGN network
- "Zero touch" to customer – PSTN to VoIP upgrade can be conducted at LE with minimal subscriber impact
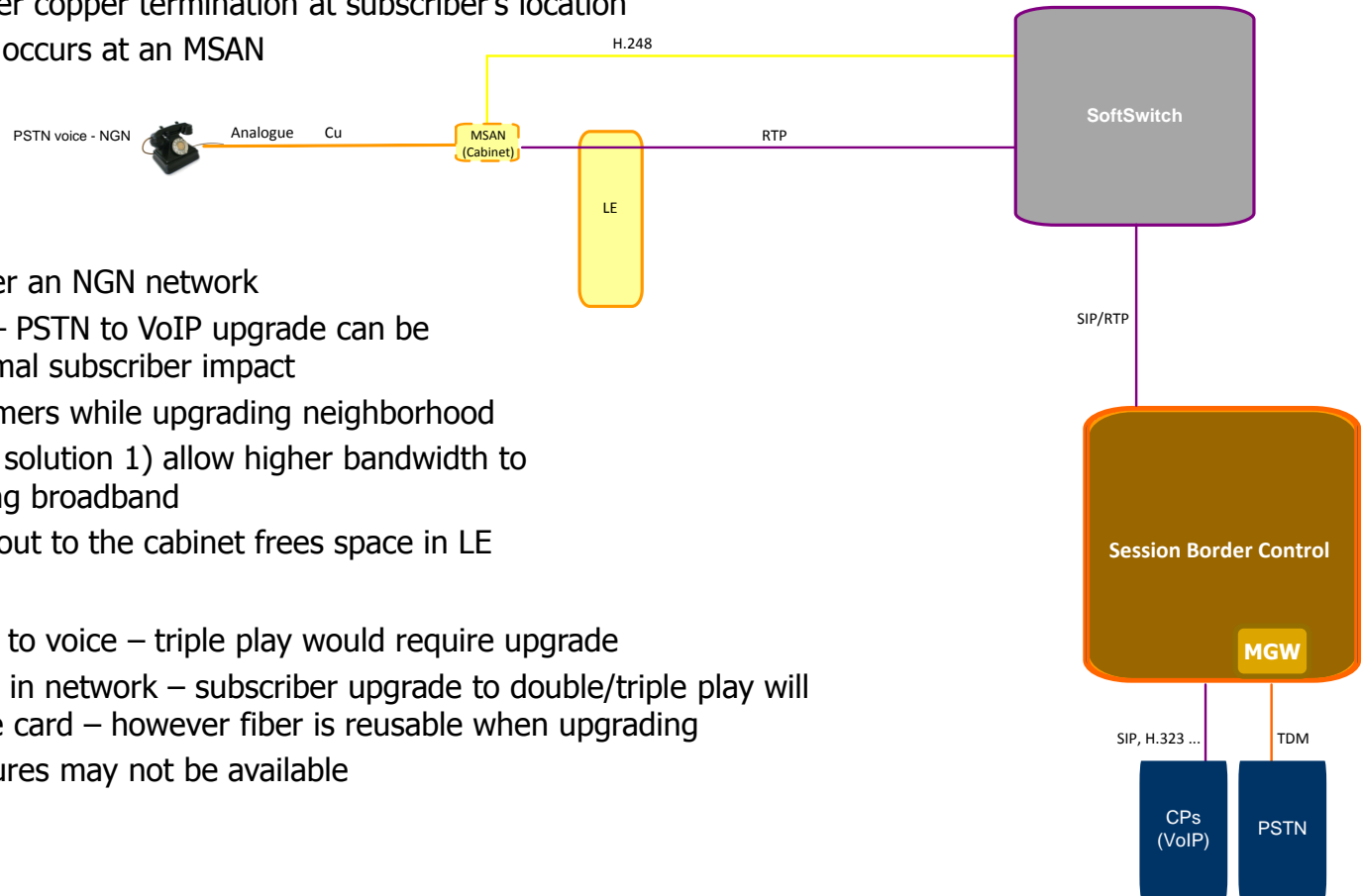- Way to serve legacy customers while upgrading neighborhood

Cons:

- Access loop service limited to voice – triple play would require upgrade
- Stranded investment in network – subscriber upgrade to double/triple play will require replacement of line card
- Some legacy services/features may not be available

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Voice Solution 2 – POTS Emulation over Analog Loops/Fiber at the Cabinet

Description:

- Fiber is pushed closer to the subscriber premise than in solution 1
- POTS voice is emulated over copper termination at subscriber's location
- Analog to VoIP conversion occurs at an MSAN in the Cabinet

PSTN voice - NGN   Analogue   Cu   MSAN (Cabinet)   H.248   SoftSwitch   LE   RTP   SIP/RTP   Session Border Control   MGW   SIP, H.323 ...   TDM   CPs (VoIP)   PSTN

Pros:

- Allows POTS emulation over an NGN network
- "Zero touch" to customer – PSTN to VoIP upgrade can be conducted at LE with minimal subscriber impact
- Way to serve legacy customers while upgrading neighborhood
- Shorter loop lengths (than solution 1) allow higher bandwidth to subscriber's neighbors using broadband
- Pushing MSAN electronics out to the cabinet frees space in LE
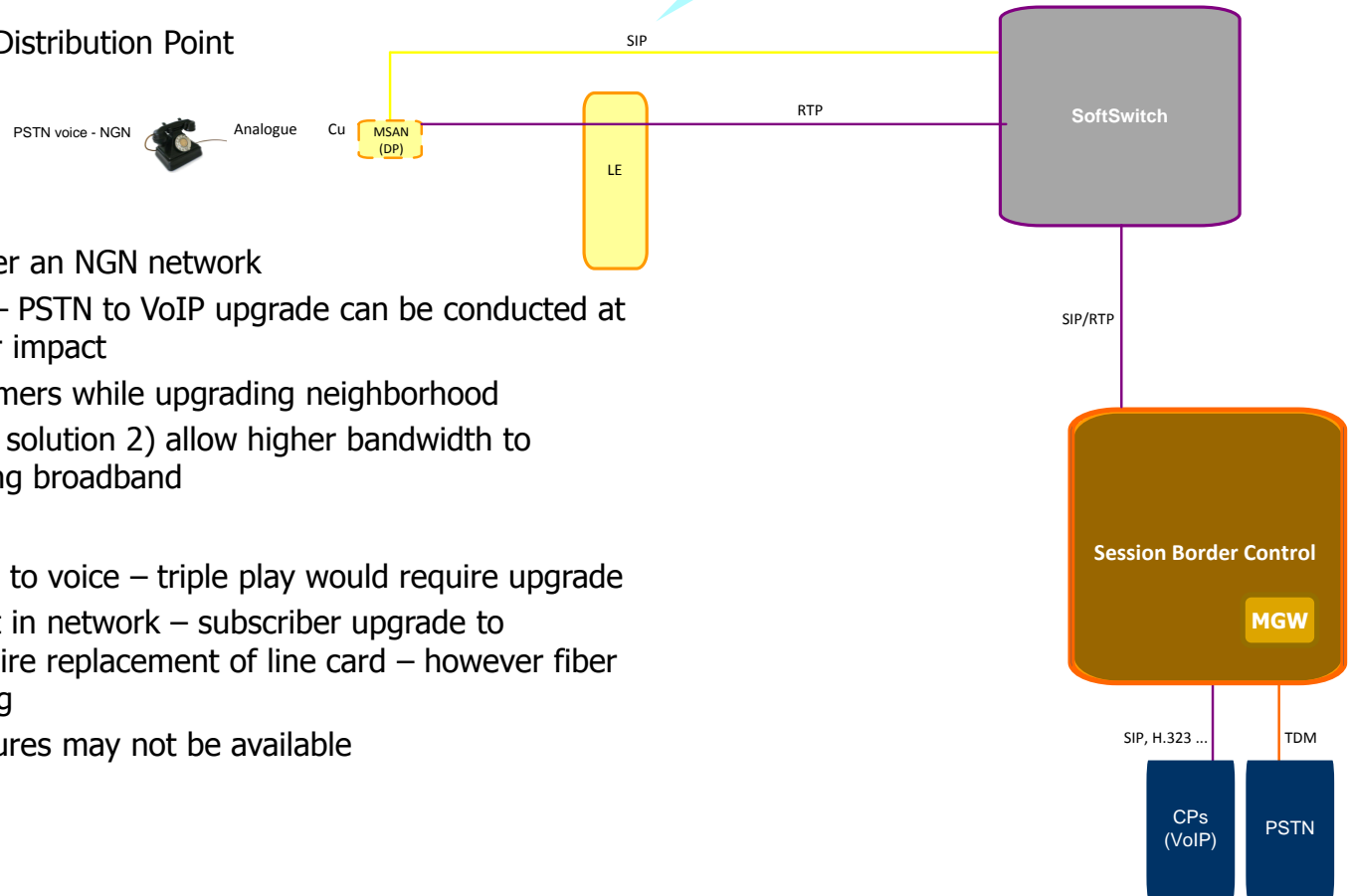
Cons:

- Access loop service limited to voice – triple play would require upgrade
- Some stranded investment in network – subscriber upgrade to double/triple play will require replacement of line card – however fiber is reusable when upgrading
- Some legacy services/features may not be available

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Voice Solution 3 – POTS Emulation over Analog Loops/Fiber at the Distribution Point

At some point, the SoftSwitch will reach a scalability limit on the number of H.248 gateways it can control and the smaller end points will need to be controlled by SIP

Description:

- Fiber is pushed even closer to the subscriber premise than in solution 2
- POTS voice is emulated over copper termination at subscriber's location
- Analog to VoIP conversion occurs at an MSAN at the Distribution Point

Pros:

- Allows POTS emulation over an NGN network
- "Zero touch" to customer – PSTN to VoIP upgrade can be conducted at LE with minimal subscriber impact
- Way to serve legacy customers while upgrading neighborhood
- Shorter loop lengths (than solution 2) allow higher bandwidth to subscriber's neighbors using broadband

Cons:

- Access loop service limited to voice – triple play would require upgrade
- Some stranded investment in network – subscriber upgrade to double/triple play will require replacement of line card – however fiber is reusable when upgrading
- Some legacy services/features may not be available

PSTN voice - NGN   Analogue   Cu   MSAN (DP)   SIP   LE   RTP   SoftSwitch   SIP/RTP   Session Border Control   MGW   SIP, H.323 ...   TDM   CPs (VoIP)   PSTN

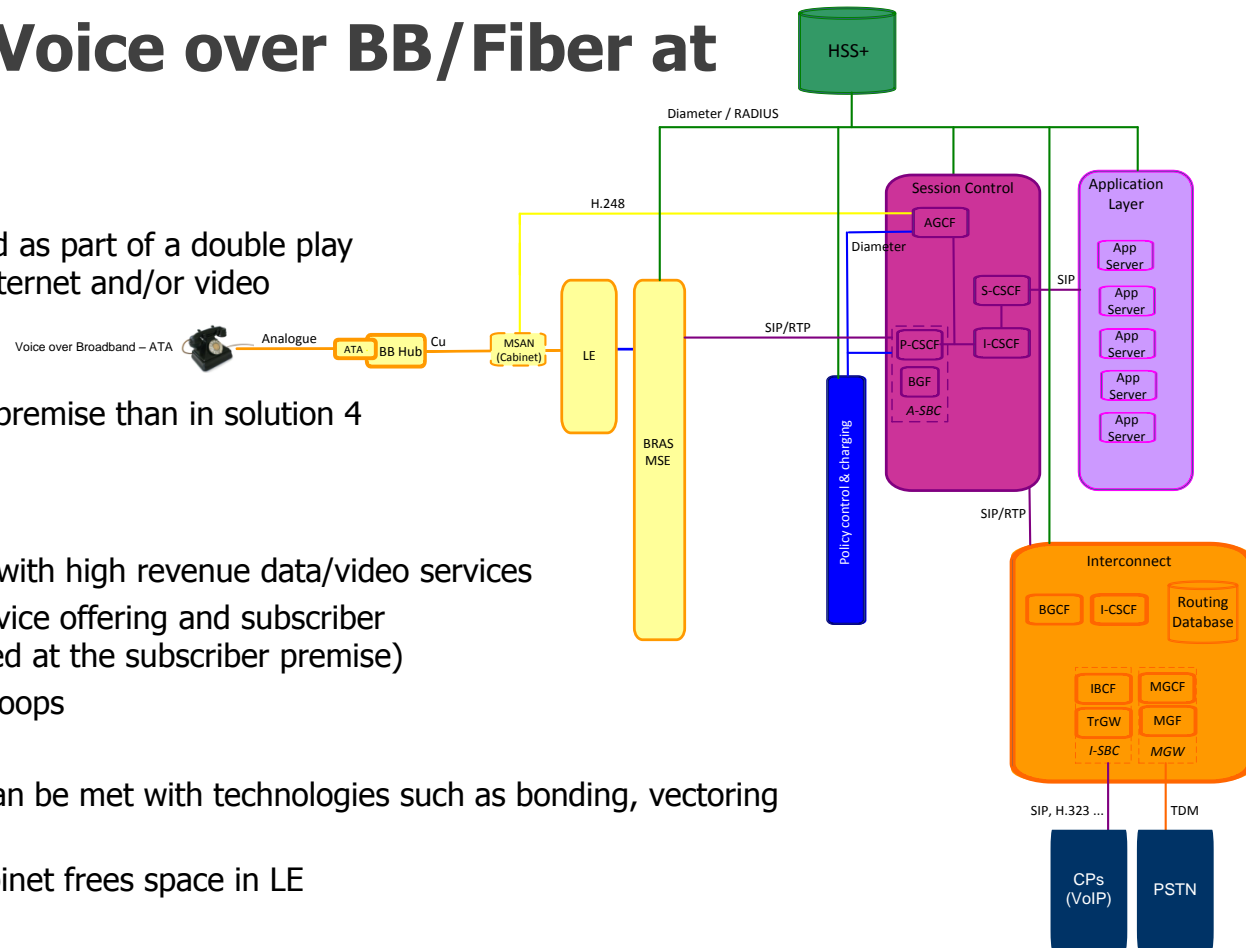# Voice Solution 4 – Voice over BB/Fiber at the LE

Description:

- Typically, the telephony service is offered as part of a double play or triple play offering with high speed internet and/or video
- The copper loops extend from the LE to the premise. The solution is limited to areas close to LE buildings

Voice over Broadband – ATA

Analogue

ATA · BB Hub

Cu

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- Minimal modification to legacy PSTN service offering and subscriber expectations (i.e., ATA has to be deployed at the subscriber premise)
- Leverages existing copper loops
- CPE can be reused
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode

Cons:

- Offering limited to premises at short distances from LE (as determined by HSI speeds)
- Providing power to the ATA may be an issue
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise

HSS+

Diameter / RADIUS

H.248

Diameter

MSAN (LE)

BRAS MSE

Policy control & charging

Session Control
- AGCF
- S-CSCF
- P-CSCF
- I-CSCF
- BGF
- A-SBC

SIP/RTP

Application Layer
- App Server
- App Server
- App Server
- App Server
- App Server

SIP

SIP/RTP

Interconnect
- BGCF
- I-CSCF
- Routing Database
- IBCF
- MGCF
- TrGW
- MGF
- I-SBC
- MGW

SIP, H.323 ...

TDM

CPs (VoIP)

PSTN

- In this case, the voice service shares a pathway with other services terminating at the premise. Additional functions to dynamically manage the bandwidth become necessary. An IMS core is deployed to provide these functions.

- The cost of evolving to IMS depends on the specific SoftSwitch being used

Voice Solution 5 – Voice over BB/Fiber at the Cabinet

Descripion:

- Typically, the telephony service is offered as part of a double play or triple play offering with high speed internet and/or video
- The copper loops extend from the cabinet to the premise.
- Fiber is pushed closer to the subscriber premise than in solution 4

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- Minimal modification to legacy PSTN service offering and subscriber expectations (i.e., ATA has to be deployed at the subscriber premise)
- Leverages part or all of existing copper loops
- CPE can be reused
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- Pushing MSAN electronics out to the cabinet frees space in LE

Cons:

- Offering reaches more subscribers than solution 4, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- Providing power to the ATA may be an issue
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be shortened and fiber pushed closer to the premise

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Voice Solution 6 – Voice over BB/Fiber at the DP

Description:

- Typically, the telephony service is offered as part of a double play or triple play offering with high speed internet and/or video
- The copper loops extend from the DP to the premise.
- Fiber is pushed closer to the subscriber premise than in solution 5

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- Minimal modification to legacy PSTN service offering and subscriber expectations (i.e., ATA has to be deployed at the subscriber premise)
- Leverages part of existing copper loops
- CPE can be reused
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode

Cons:

- Offering reaches more subscribers than solution 5, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- Providing power to the ATA may be an issue
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be eliminated and an FTTP solution deployed

Voice over Broadband – ATA

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Voice Solution 7 – VoIP Terminal Equipment/Fiber at the LE
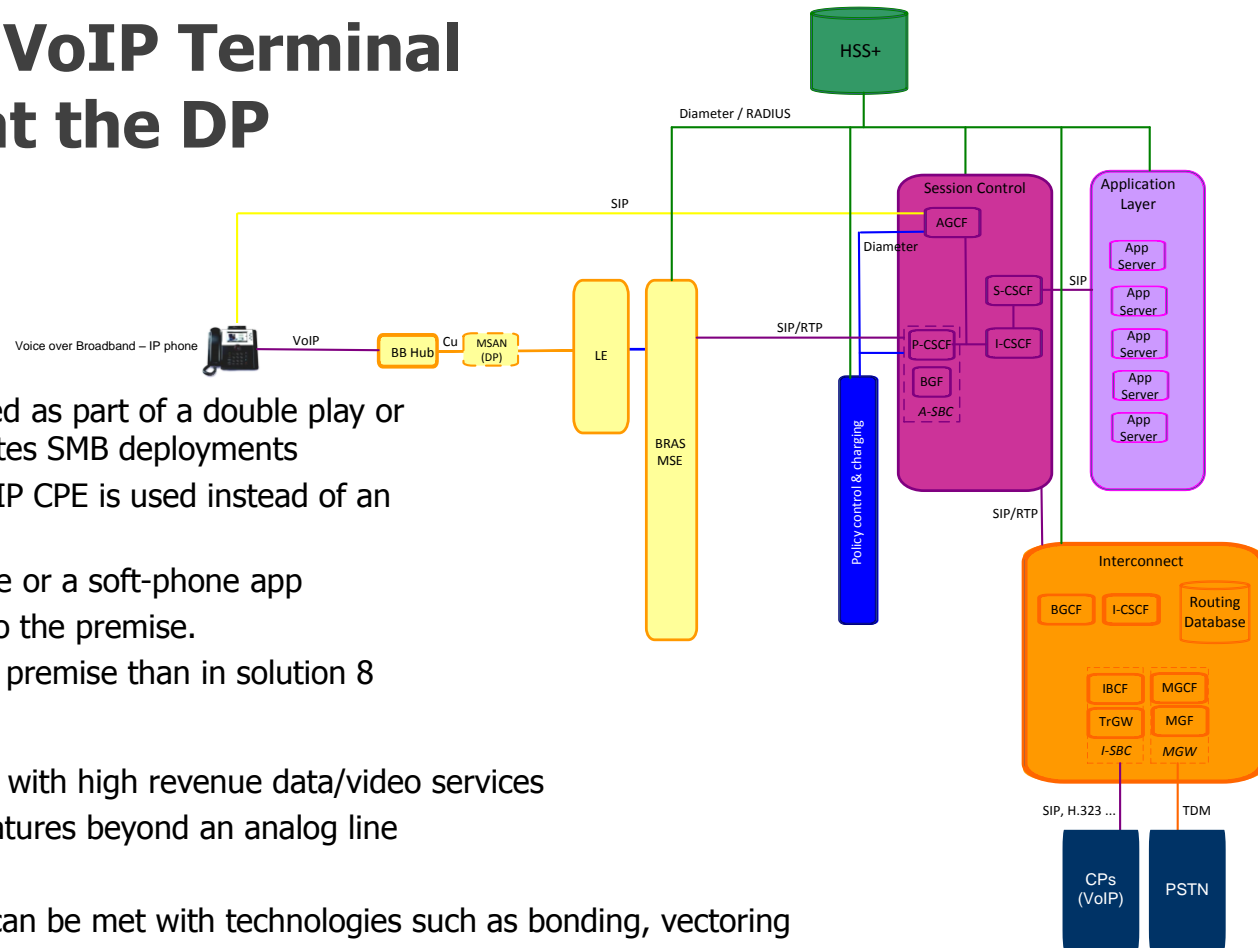
Description:

- Typically, the telephony service is offered as part of a double play or triple play – VoIP phone typically indicates SMB deployments
- This differs from solution 4 in that a VoIP CPE is used instead of an ATA and analog CPE
- VoIP CPE can be either a physical phone or a soft-phone app
- The copper loops extend from the LE to the premise. The solution is limited to areas close to LE buildings

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- VoIP phones may support additional features beyond an analog line
- Leverages existing copper loops
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode

Cons:

- Offering limited to premises at short distances from LE (as determined by HSI speeds)
- Current cost of a VoIP CPE >> analog phone
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise

HSS+

Diameter / RADIUS

SIP

Voice over Broadband – IP phone

VoIP

BB Hub

Cu

MSAN (LE)

BRAS MSE

SIP/RTP

Diameter

Policy control & charging

Session Control

AGCF

S-CSCF

P-CSCF

I-CSCF

BGF

A-SBC

Application Layer

App Server

App Server

App Server

App Server

App Server

SIP

SIP/RTP

Interconnect

BGCF

I-CSCF

Routing Database

IBCF

MGCF

TrGW

MGF

I-SBC

MGW

SIP, H.323 ...

TDM

CPs (VoIP)

PSTN

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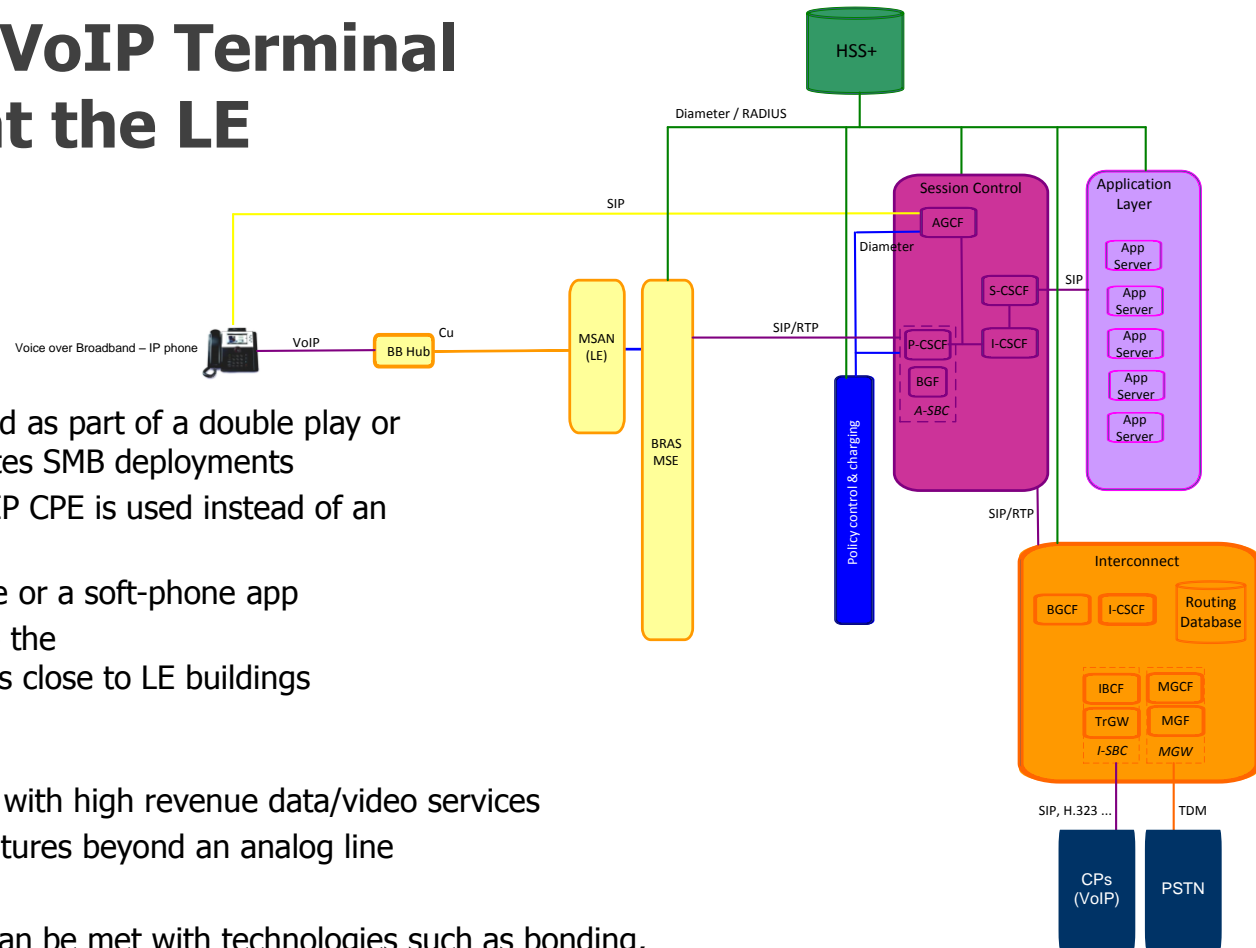
Voice Solution 8 – VoIP Terminal Equipment/Fiber at the Cabinet

HSS+

Diameter / RADIUS

SIP

Session Control

AGCF

Diameter

Application Layer

App Server
App Server
App Server
App Server
App Server

S-CSCF

SIP

Voice over Broadband – IP phone

VoIP

BB Hub

Cu

MSAN (Cabinet)

LE

SIP/RTP

P-CSCF

I-CSCF

BGF

A-SBC

BRAS MSE

Policy control & charging

SIP/RTP

Interconnect

BGCF | I-CSCF | Routing Database

IBCF | MGCF

TrGW | MGF

I-SBC | MGW

SIP, H.323 ...

TDM

CPs (VoIP)

PSTN

Description:

- Typically, the telephony service is offered as part of a double play or triple play – VoIP phone typically indicates SMB deployments
- This differs from solution 5 in that a VoIP CPE is used instead of an ATA and analog CPE
- VoIP CPE can be either a physical phone or a soft-phone app
- The copper loops extend from the cabinet to the premise.
- Fiber is pushed closer to the subscriber premise than in solution 7

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- VoIP phones may support additional features beyond an analog line
- Leverages part or all of existing copper loops
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- Pushing MSAN electronics out to the cabinet frees space in LE

Cons:

- Offering reaches more subscribers than solution 7, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- Current cost of a VoIP CPE >> analog phone
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be shortened and fiber pushed closer to the premise

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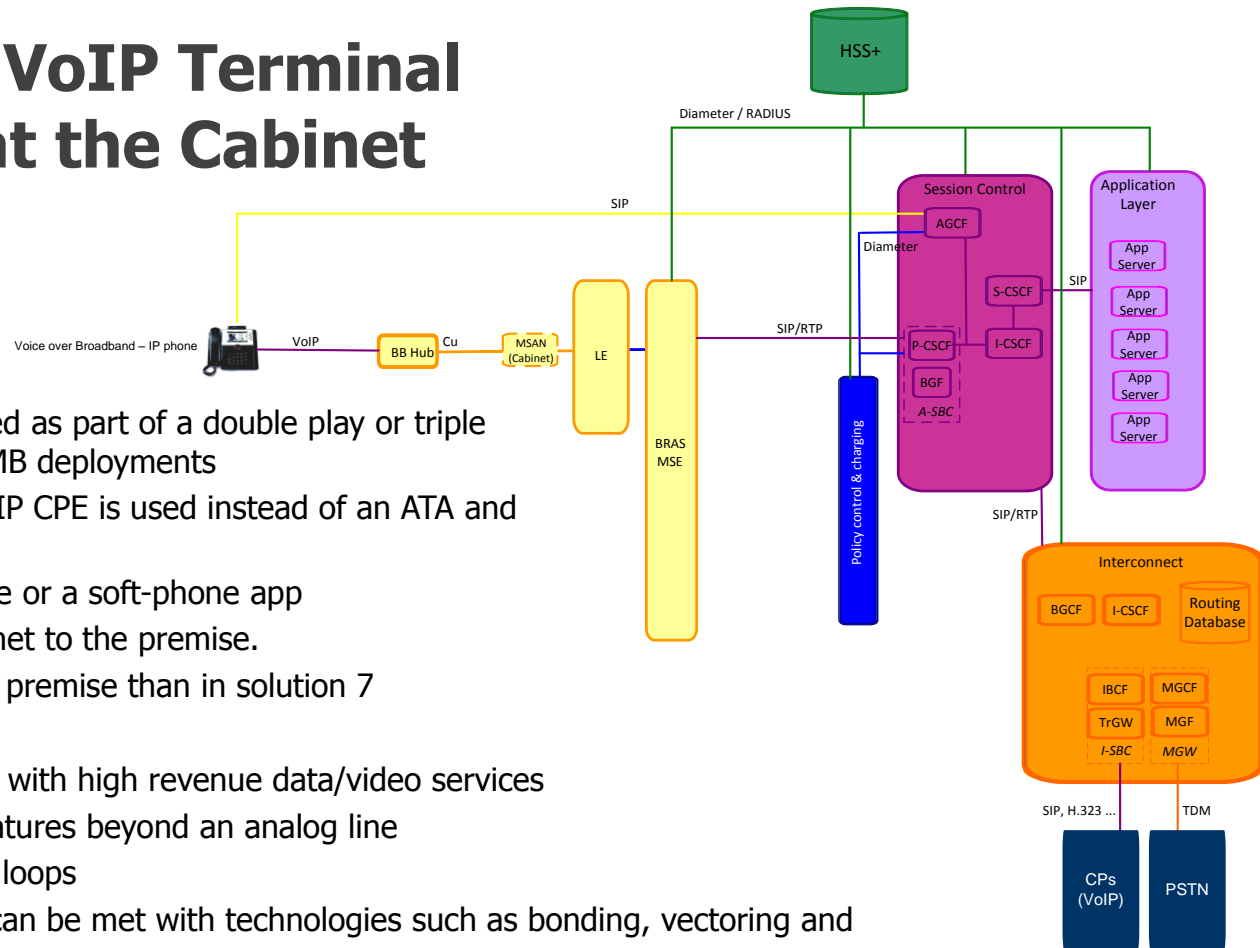
Voice Solution 9 – VoIP Terminal Equipment/Fiber at the DP

Description:

- Typically, the telephony service is offered as part of a double play or triple play – VoIP phone typically indicates SMB deployments
- This differs from solution 6 in that a VoIP CPE is used instead of an ATA and analog CPE
- VoIP CPE can be either a physical phone or a soft-phone app
- The copper loops extend from the DP to the premise.
- Fiber is pushed closer to the subscriber premise than in solution 8

Pros:

- Solution can competitively bundle voice with high revenue data/video services
- VoIP phones may support additional features beyond an analog line
- Leverages part of existing copper loops
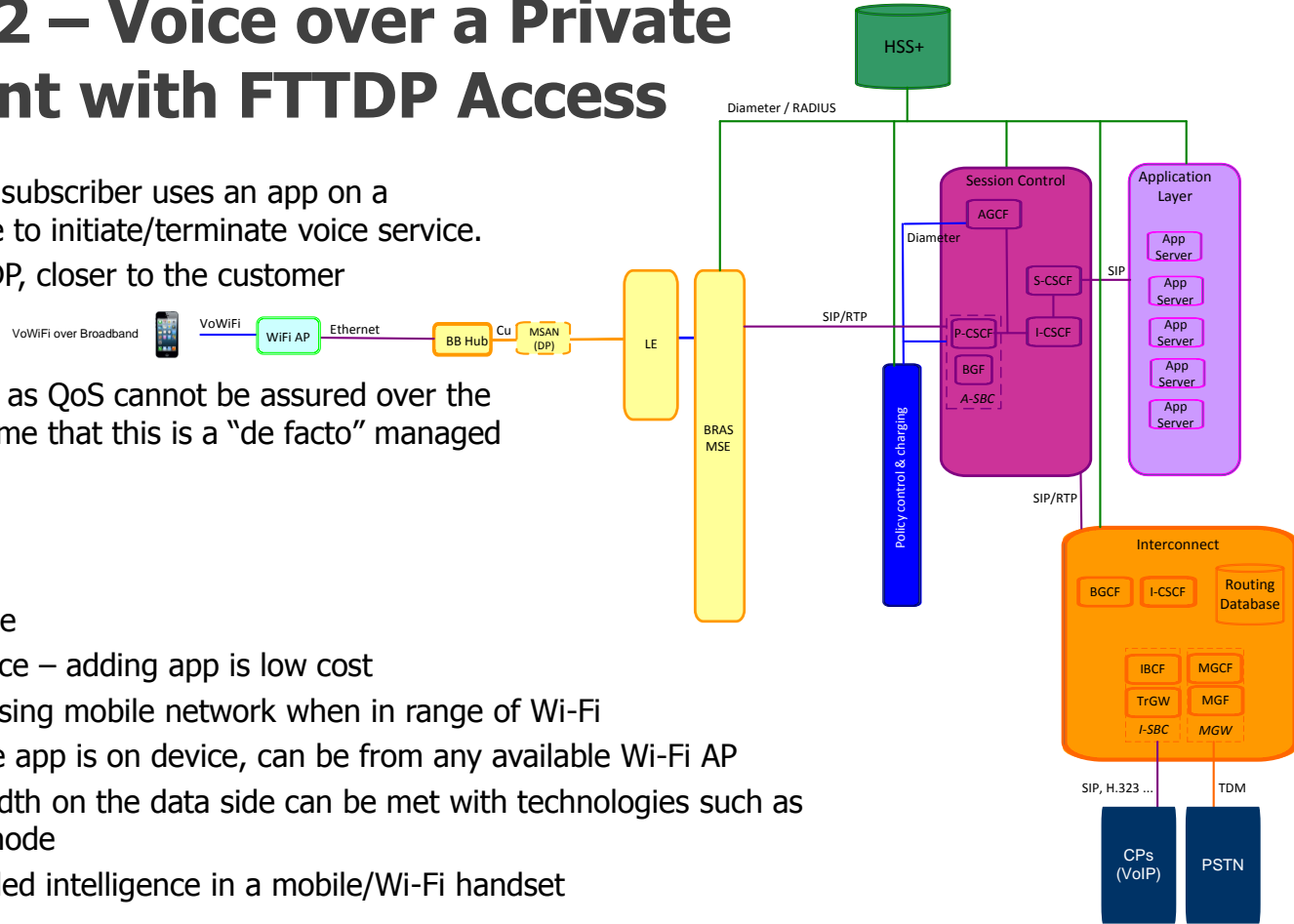- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode

Cons:

- Offering reaches more subscribers than solution 5, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- Current cost of a VoIP CPE >> analog phone
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be eliminated and an FTTP solution deployed

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Voice Solution 10 – Voice over a Private Wi-Fi Access Point with FTTLE Access

Description:

- In this case, the subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service
- The access is similar to solution 4 in that the copper loops extend from the LE to the premise. The solution is limited to areas close to LE buildings
- Technically, not a managed service as QoS cannot be assured over the Wi-Fi interface. However, we assume that this is a "de facto" managed private Wi-Fi network

Pros:

- Solution part of a data/video bundle
- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, can be from any available Wi-Fi AP
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- This solution may leverage the added intelligence in a mobile/Wi-Fi handset

Cons:

- Offering limited to premises at short distances from LE (as determined by HSI speeds)
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to have possession of Wi-Fi device and app development is needed

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Voice Solution 11 – Voice over a Private Wi-Fi Access Point with FTTCabinet Access

Description:

- Similar to solution 10, the subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service.

- However, fiber is deployed to the cabinet, closer to the customer premise. The copper loops extend from the cabinet to the premise.

- Technically, not a managed service as QoS cannot be assured over the Wi-Fi interface. However, we assume that this is a "de facto" managed private Wi-Fi network

Pros:

- Solution part of a data/video bundle
- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, can be from any available Wi-Fi AP
- Pushing MSAN electronics out to the cabinet frees space in LE
- This solution may leverage the added intelligence in a mobile/Wi-Fi handset
- Initial demands for greater bandwidth on the data side can be met with technologies such as bonding/vectoring/phantom mode

Cons:

- Offering reaches more subscribers than solution 10, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be shortened and fiber pushed closer to the premise
- Requires subscriber to have possession of Wi-Fi device and app development is needed

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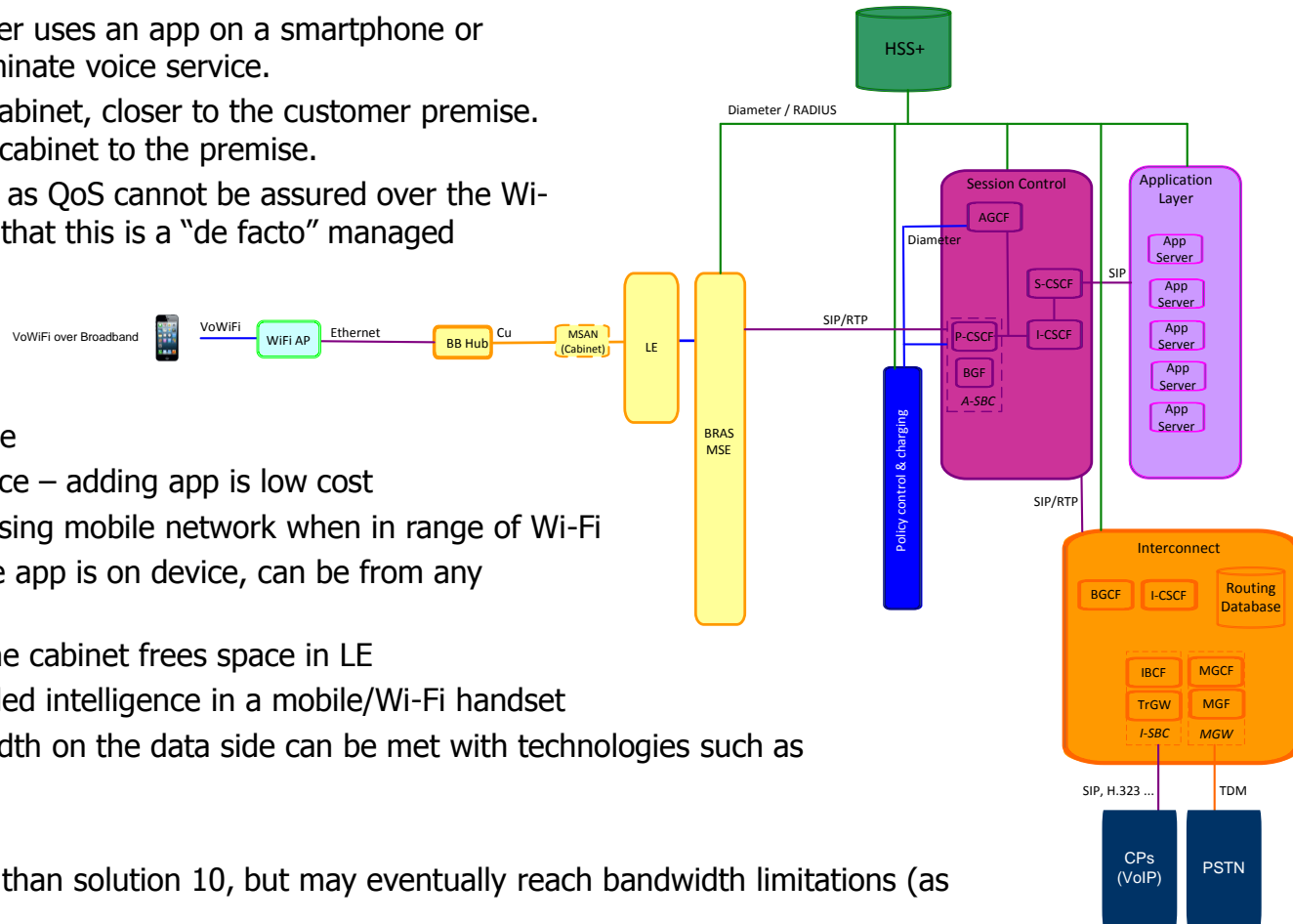
Voice Solution 12 – Voice over a Private Wi-Fi Access Point with FTTDP Access

Description:

- Similar to solutions 10 and 11, the subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service.
- However, fiber is deployed to the DP, closer to the customer premise. The copper loops extend from the DP to the premise.
- Technically, not a managed service as QoS cannot be assured over the Wi-Fi interface. However, we assume that this is a "de facto" managed private Wi-Fi network

Pros:

- Solution part of a data/video bundle
- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, can be from any available Wi-Fi AP
- Initial demands for greater bandwidth on the data side can be met with technologies such as bonding, vectoring and phantom mode
- This solution may leverage the added intelligence in a mobile/Wi-Fi handset

Cons:

- Offering reaches more subscribers than solution 1o, but may eventually reach bandwidth limitations (as determined by HSI speeds)
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, the copper loops will need to be eliminated and an FTTP solution deployed
- Requires subscriber to have possession of Wi-Fi device and app development is needed

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Voice Solution 13 – POTS Simulation over FTTP

Description:

- The fiber terminates at the subscriber premise (at an ONT) providing triple play broadband
- Telephony service is provided through an RJ11 jack on the ATA that is integrated into the ONT
- Variations of this solution exist depending on the FTTP technology being deployed
- Solution is architecturally identical to number 14, the difference being that subscriber only signs up for voice (as opposed to triple play in 14)
- Presumably deployed in isolated instances with single or very small number of voice only customers in a larger, predominantly triple play serving areas
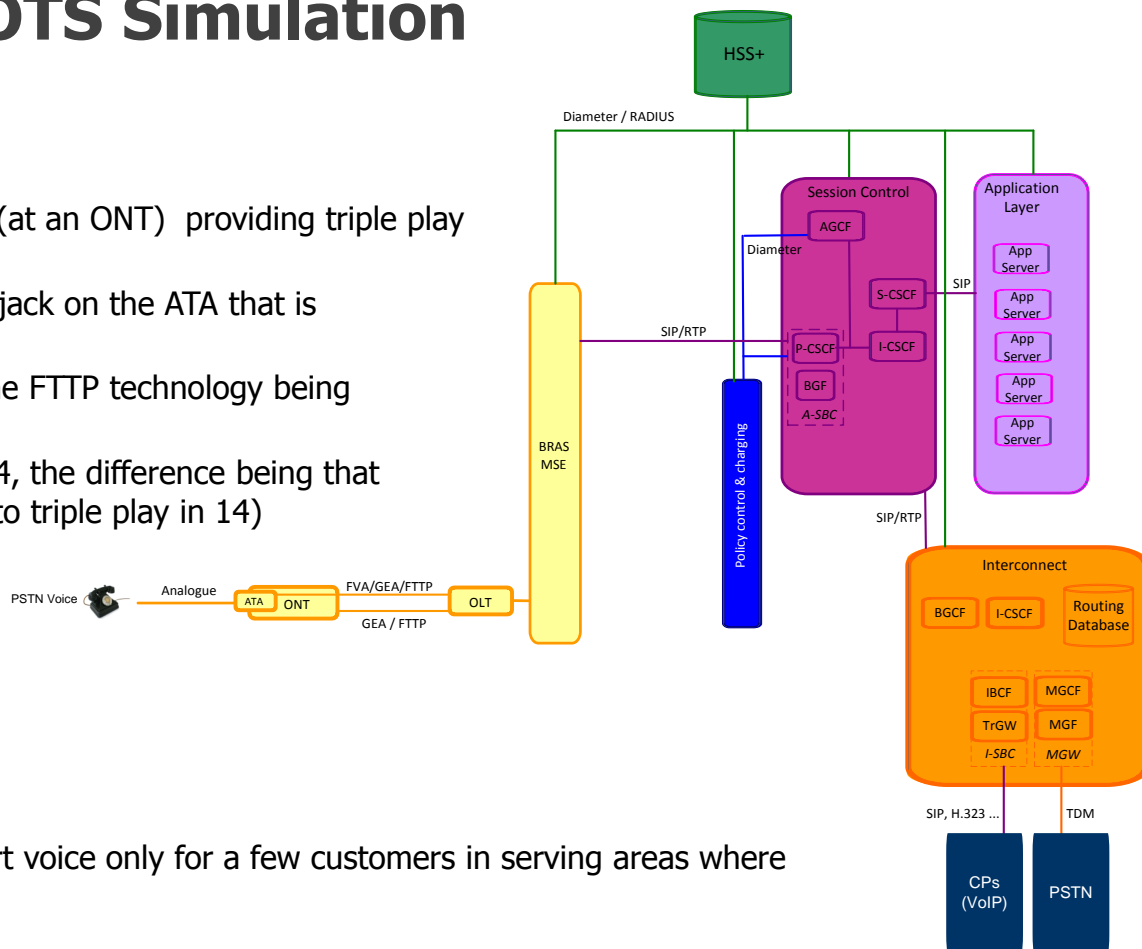
Pros:

- Valuable if the service provider needs to support voice only for a few customers in serving areas where copper is being retired or not available

Cons:

- Deploying an FTTP solution represents a significant CapEx cost – cannot be justified from voice revenue only
- The telephony service needs to be powered at the premise (presumably with battery back up in case of power outages)

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Voice Solution 14 – Voice over BB, FTTP Access with an ATA Device Integrated in the ONT

Description:

- The fiber terminates at the subscriber premise (at an ONT) providing triple play broadband
- Telephony service is provided through an RJ11 jack on the ATA that is integrated into the ONT
- Variations of this solution exist depending on the PON technology being deployed

Pros:

- Provides telephony as part of double play/triple play FTTP offering
- Lowest impact to customer of all FTTP variations – customer will be able to use existing CPE

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- The telephony service needs to be powered at the premise (presumably with battery back up in case of power outages)

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Diameter / RADIUS

Session Control
AGCF
S-CSCF
I-CSCF
P-CSCF
BGF
A-SBC
Diameter

Application Layer
App Server
App Server
App Server
App Server
App Server

SIP

Policy control & charging

BRAS MSE

SIP/RTP

SIP/RTP

Interconnect
BGCF | I-CSCF | Routing Database
IBCF | MGCF
TrGW | MGF
I-SBC | MGW

SIP, H.323 ...   TDM

CPs (VoIP)   PSTN

PTN Voice   Analogue   ATA ONT   FVA/GEA/FTTP   OLT   GEA / FTTP

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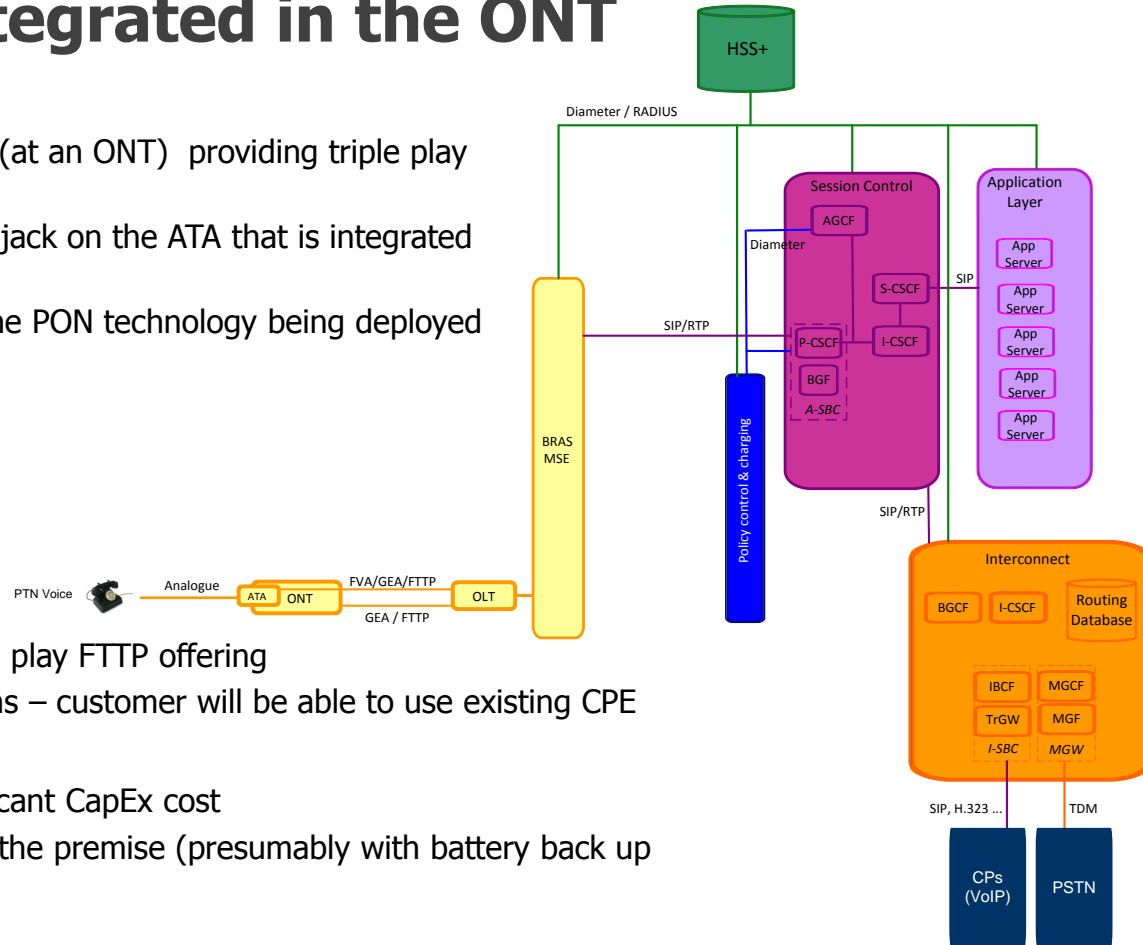
Voice Solution 15 – Voice over BB, FTTP Access with a Separate ATA Device

Description:

- The fiber terminates at the subscriber premise (at an ONT) providing triple play broadband
- Telephony service is provided through an RJ11 jack on an ATA connected to the ONT. This is slightly different from 14 in that the ATA is separate from the ONT.
- Variations of this solution exist depending on the PON technology being deployed
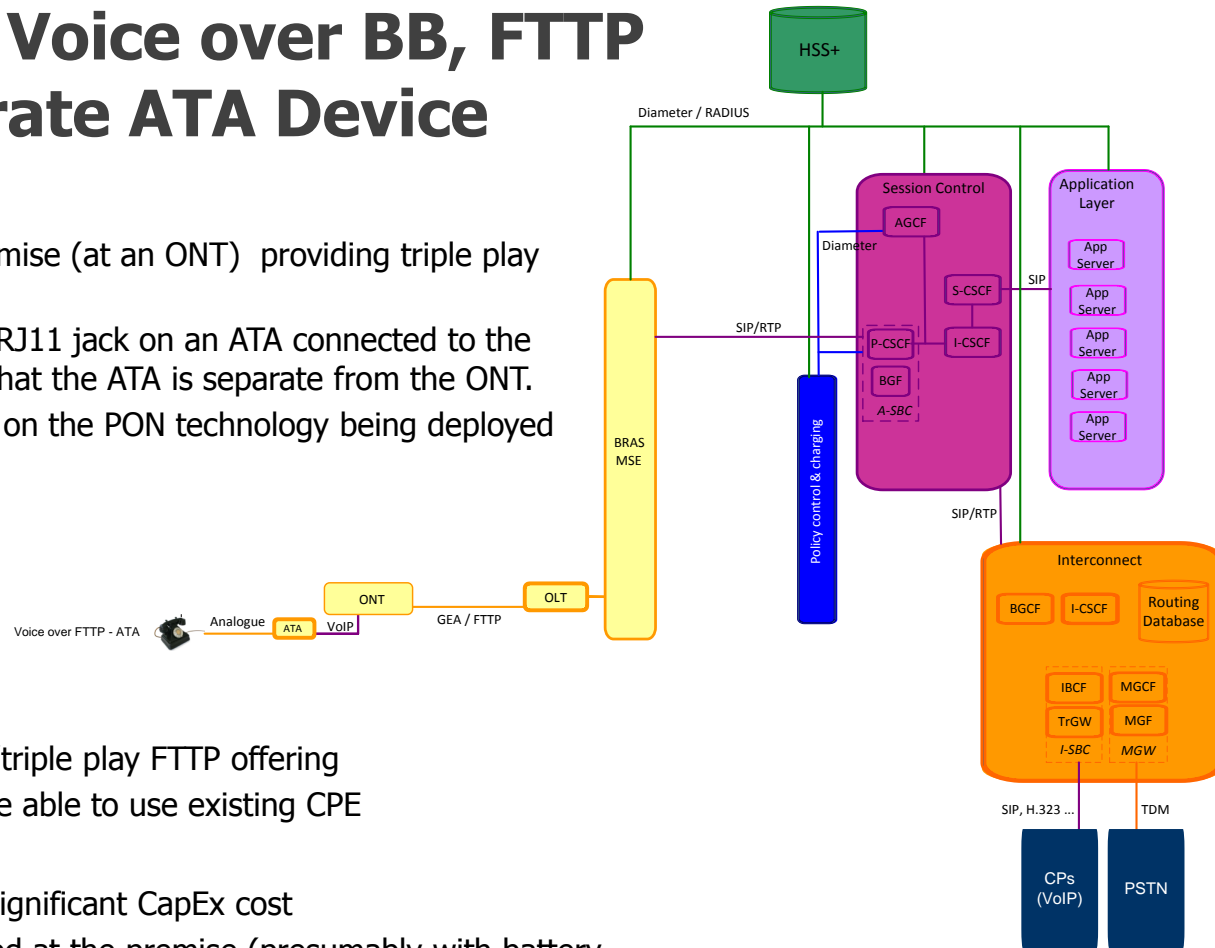
Pros:

- Provides telephony as part of double play/triple play FTTP offering
- Low impact to customer – customer will be able to use existing CPE

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- The telephony service needs to be powered at the premise (presumably with battery back up in case of power outages)
- Two separate CPE elements instead of one

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Voice Solution 16 – Voice Over Wi-Fi AP/FTTDP Access

Description:

- The fiber terminates at the subscriber premise (at an ONT) providing triple play broadband
- VoIP phone typically indicates SMB deployments
- Telephony service is provided via a VoIP phone, which can be a physical device or an application on a PC (softphone)
- Variations of this solution exist depending on the PON technology being deployed
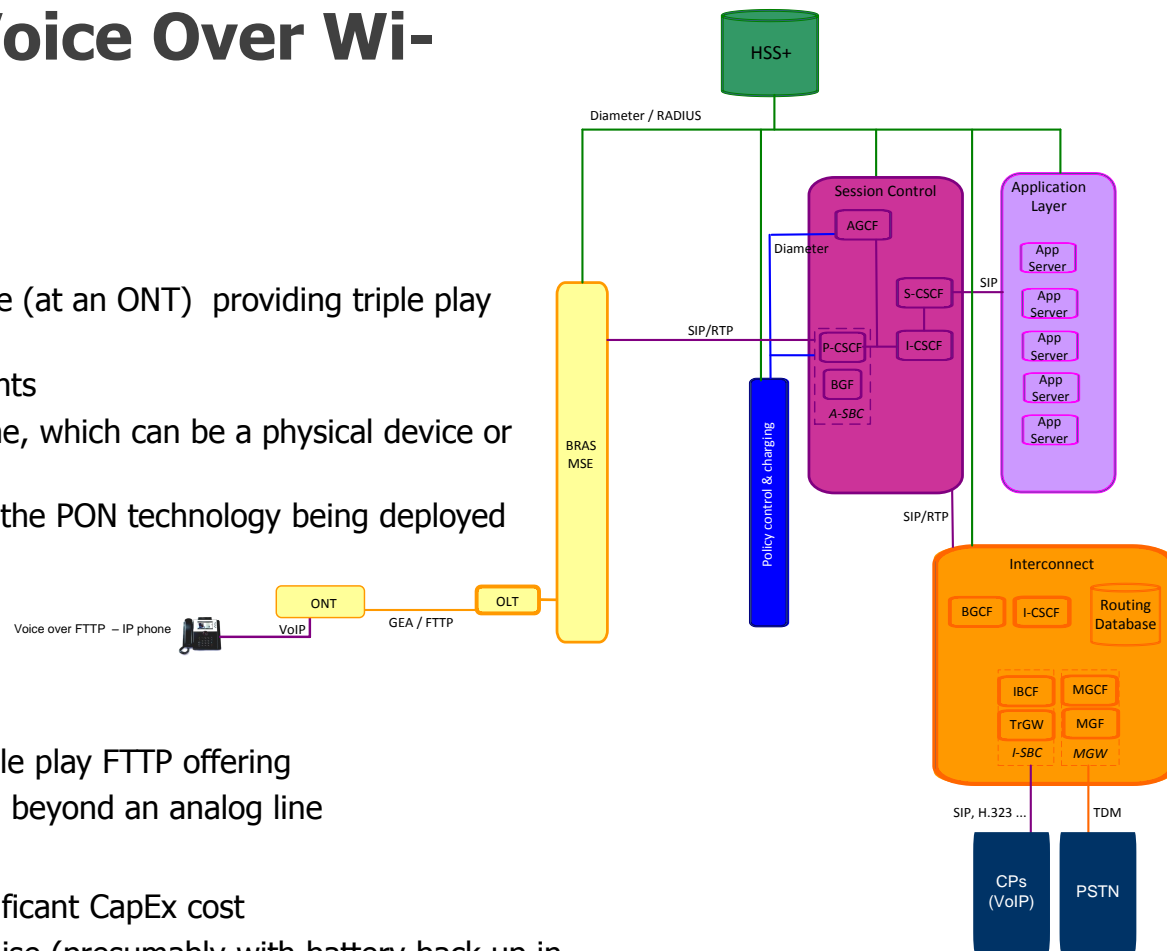
Pros:

- Provides telephony as part of double play/triple play FTTP offering
- VoIP phones may support additional features beyond an analog line

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- The service needs to be powered at the premise (presumably with battery back up in case of power outages)
- Current cost of a VoIP CPE >> analog phone

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Voice Solution 17 – Voice Over Wi-Fi AP/FTTP Access

Description:

- The fiber terminates at the subscriber premise (at an ONT) providing triple play broadband. A Wi-Fi AP is connected to the ONT
- The subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service
- Variations of this solution exist depending on the PON technology being deployed
- Technically, not a managed service as QoS cannot be assured over the Wi-Fi interface. However, we assume that this is a "de facto" managed private Wi-Fi network
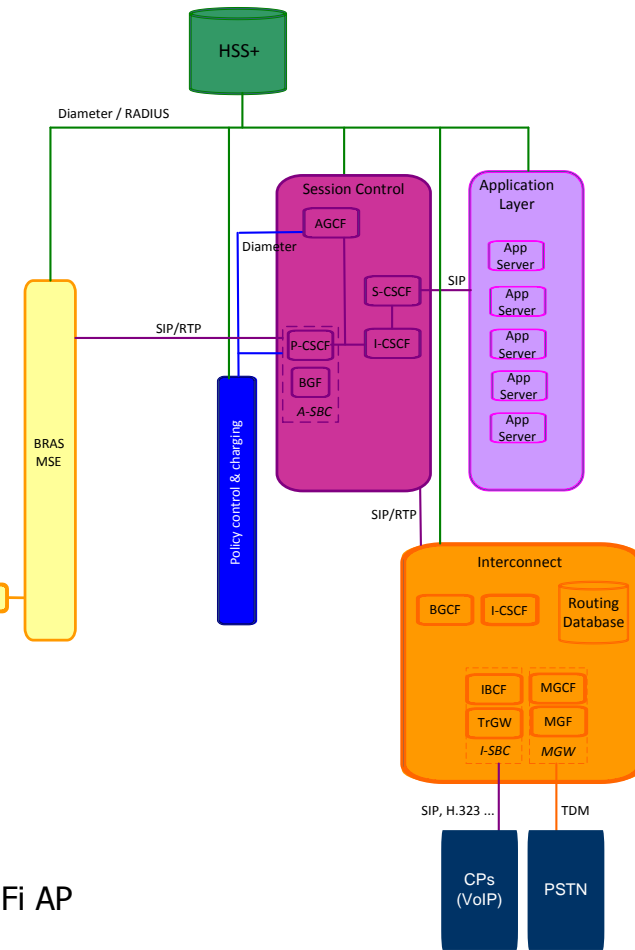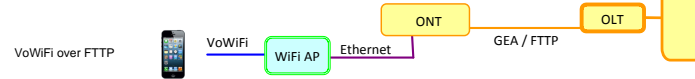
Pros:

- Provides telephony as part of double play/triple play FTTP offering
- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, can be from any available Wi-Fi AP
- This solution may leverage the added intelligence in a mobile/Wi-Fi handset

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- Requires subscriber to have possession of Wi-Fi device and app development is needed

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Voice Solution 18 – Voice over LTE Small Cell/FTTLE Access

Description:

- Copper loops extend from the LE to the premise. The solution is limited to areas close to LE buildings
- A 2G/3G small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
- The subscriber then uses existing mobile device for making voice calls

Pros:

- Leverages existing copper loops
- This solution may leverage the added intelligence in a mobile handset
- Subscriber can have service in mobile areas
- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Depending on morphology, small cell need not be deployed at every location, saving cost
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring & phantom mode

Cons:

- Offering limited to premises at short distances from LE (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- Special attention may be needed if termination is a fax line
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and mobile network infrastructure. There may be special implications if a landline number is routed to a mobile line
- 2G/3G voice quality is << PSTN (or equivalent) voice

• An existing mobile network may have an HLR that can be transitioned to the HSS+. Additional features may be needed to support IMS functions.

• Mobile core elements are needed to support 2G/3G access.

HSS+

Diameter / RADIUS

Session Control
- AGCF
- S-CSCF
- P-CSCF
- I-CSCF
- BGF
- A-SBC

Diameter

Application Layer
- App Server
- App Server
- App Server
- App Server
- App Server

SIP

SIP/RTP

SIP/RTP

Policy control & charging

2/3G Femto

2/3G voice

Ethernet

Cu

BB Hub

MSAN (LE)

BRAS MSE

2G/3G mobile voice

2G/3G Mobile Core
- S/GGSN
- MSC-S
- MGW
- RNC
- Femto GW

Interconnect
- BGCF
- I-CSCF
- Routing Database
- IBCF
- MGCF
- TrGW
- MGF
- I-SBC
- MGW

SIP, H.323 ...

TDM

CPs (VoIP)

PSTN

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Voice Solution 19 – Voice over 2G/3G Small Cell/FTTCabinet Access
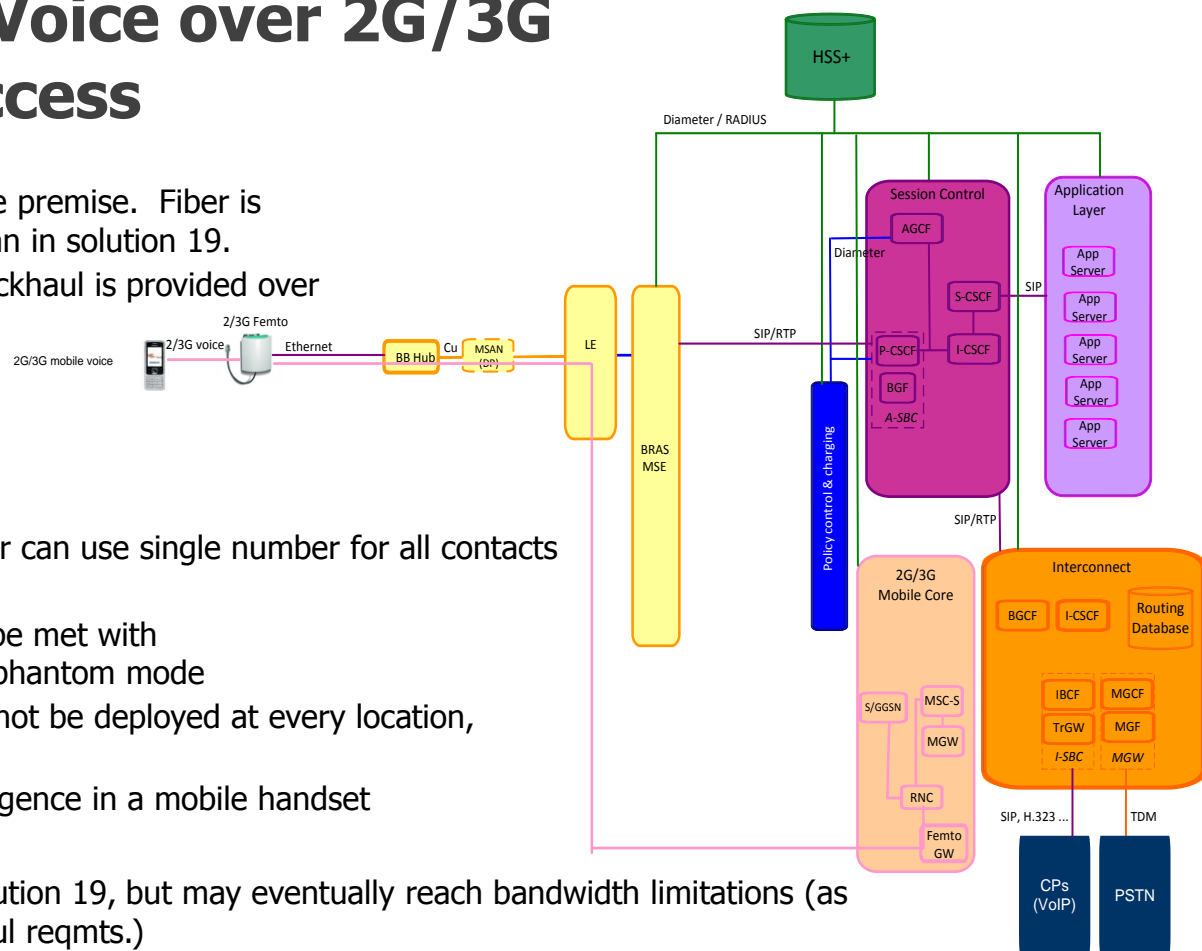
Description:

- The copper loops extend from the cabinet to the premise. Fiber is pushed closer to the subscriber premise than in solution 18
- A 2G/3G small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
- The subscriber then uses existing mobile device for making voice calls

Pros:

- Leverages part or all of existing copper loops
- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring & phantom mode
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Offering reaches more subscribers than solution 18, but may eventually reach bandwidth limitations (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- Special attention may be needed if termination is a fax line
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and mobile network infrastructure. There may be special implications if a landline number is routed to a mobile line
- 2G/3G voice quality is << PSTN (or equivalent) voice

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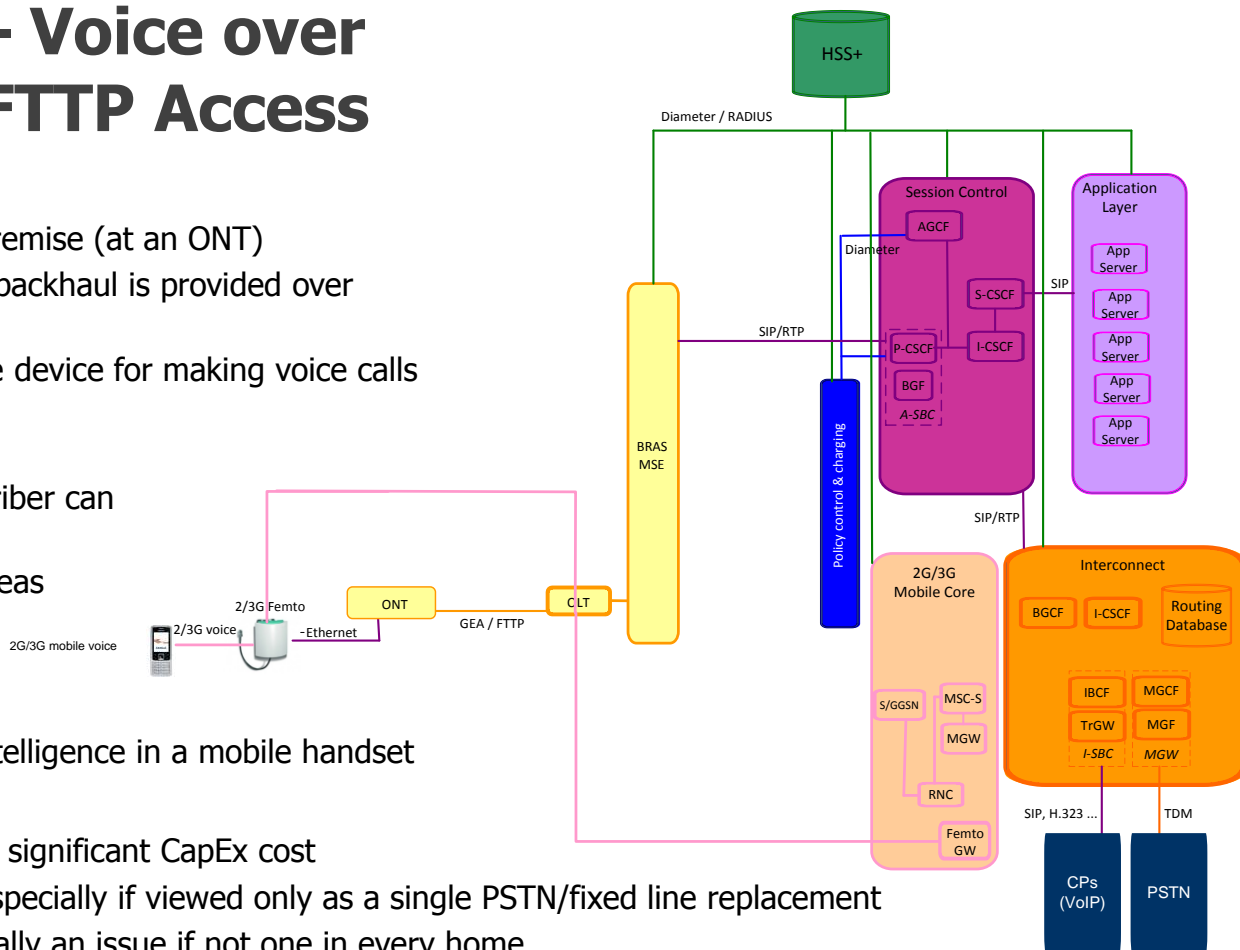# Voice Solution 20 – Voice over 2G/3G Small Cell/FTTDP Access

Description:

- The copper loops extend from the DP to the premise. Fiber is pushed closer to the subscriber premise than in solution 19.
- A 2G/3G small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
- The subscriber then uses existing mobile device for making voice calls

Pros:

- Leverages part of existing copper loops
- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring & phantom mode
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Offering reaches more subscribers than solution 19, but may eventually reach bandwidth limitations (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- Special attention may be needed if termination is a fax line
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and mobile network infrastructure. There may be special implications if a landline number is routed to a mobile line
- 2G/3G voice quality is << PSTN (or equivalent) voice

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Voice Solution 21 – Voice over 2G/3G Small Cell/FTTP Access

Description:

- The fiber terminates at the subscriber premise (at an ONT)
- A 2G/3G small cell is deployed. The cell backhaul is provided over the broadband access (FTTP) line
- The subscriber then uses existing mobile device for making voice calls

Pros:

- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
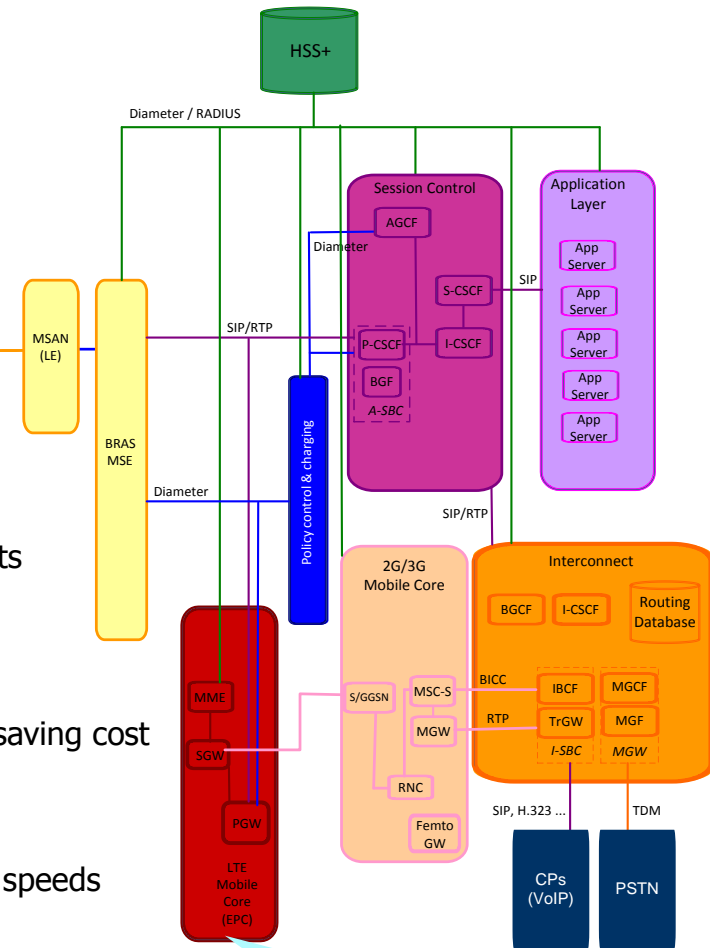- Small cell needs to be powered – especially an issue if not one in every home
- Special attention may be needed if termination is a fax line
- Requires subscriber to also be mobile customer and mobile network infrastructure. There may be special implications if a landline number is routed to a mobile line
- 2G/3G voice quality is << PSTN (or equivalent) voice

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Voice Solution 22 – Voice Over 2G/3G Mobile

Description:

- Service is provided over a 2G/3G mobile, macro-cellular network
- The subscriber uses existing mobile device for making voice calls
- A variation of the service exists where a FWT can connect to an analog phone to provide residential service over the mobile network

Pros:

- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in all mobile areas
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires full deployment of mobile network infrastructure
- Requires subscriber to also be mobile customer and mobile network infrastructure. There may be special implications if a landline number is routed to a mobile line
- Special attention may be needed if termination is a fax line
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- 2G/3G voice quality is << PSTN (or equivalent) voice

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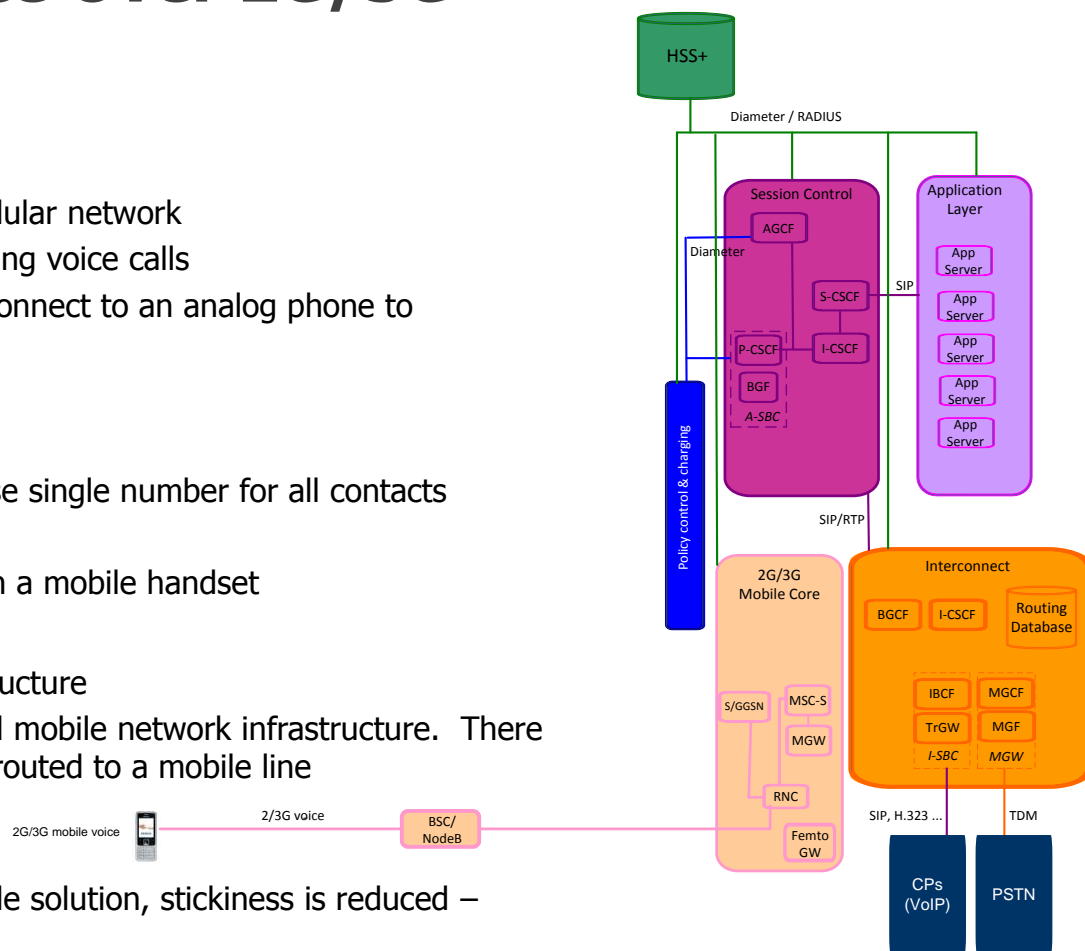
Voice Solution 23 – 2G/3G Voice over a 3rd Party/MNO Network

Description:

- Service is provided over a third party's 2G/3G mobile, macro-cellular network
- The subscriber uses existing mobile device for making voice calls
- A variation of the service exists where a FWT can connect to an analog phone to provide residential service over the mobile network

Pros:

- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in all mobile areas
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires agreement with MNO to provide service
- Special attention may be needed if termination is a fax line
- Requires subscriber to also be mobile customer. There may be special implications if a landline number is routed to a mobile line
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- 2G/3G voice quality is << PSTN (or equivalent) voice

Alcatel·Lucent
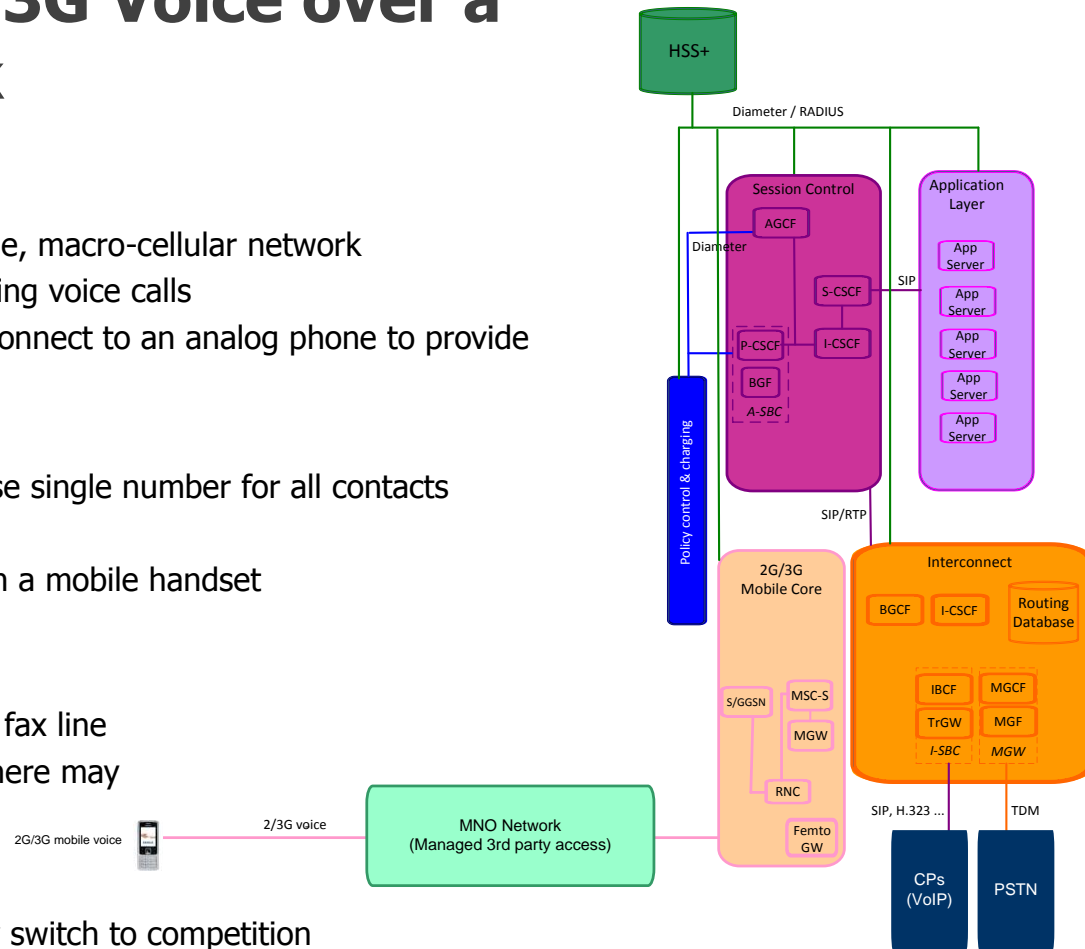
Voice Solution 24 – Voice over LTE Small Cell/FTTLE Access

Description:

- Copper loops extend from the LE to the premise. The solution is limited to areas close to LE buildings
- An LTE small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
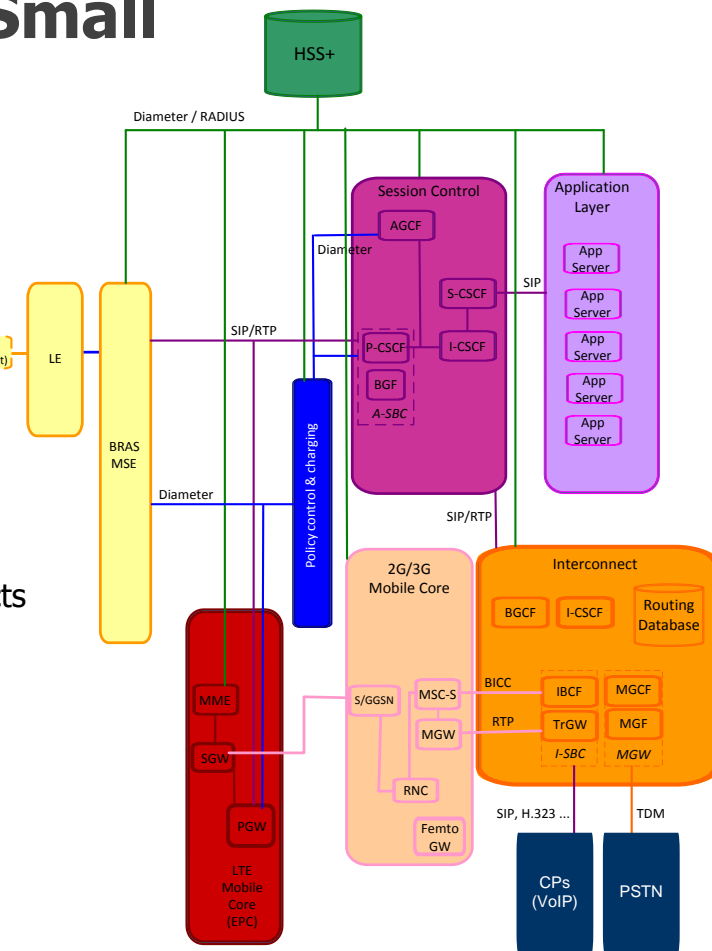- The subscriber then uses existing VoLTE device for making calls

Pros:

- Leverages existing copper loops
- Leverages LTE infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Offering limited to premises at short distances from LE (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and LTE network infrastructure
- VoLTE handsets are new, early on the technology curve – LTE is a maturing technology

- *EPC functions are deployed to support LTE access*

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Voice Solution 25 – Voice over LTE Small Cell/FTTCabinet Access
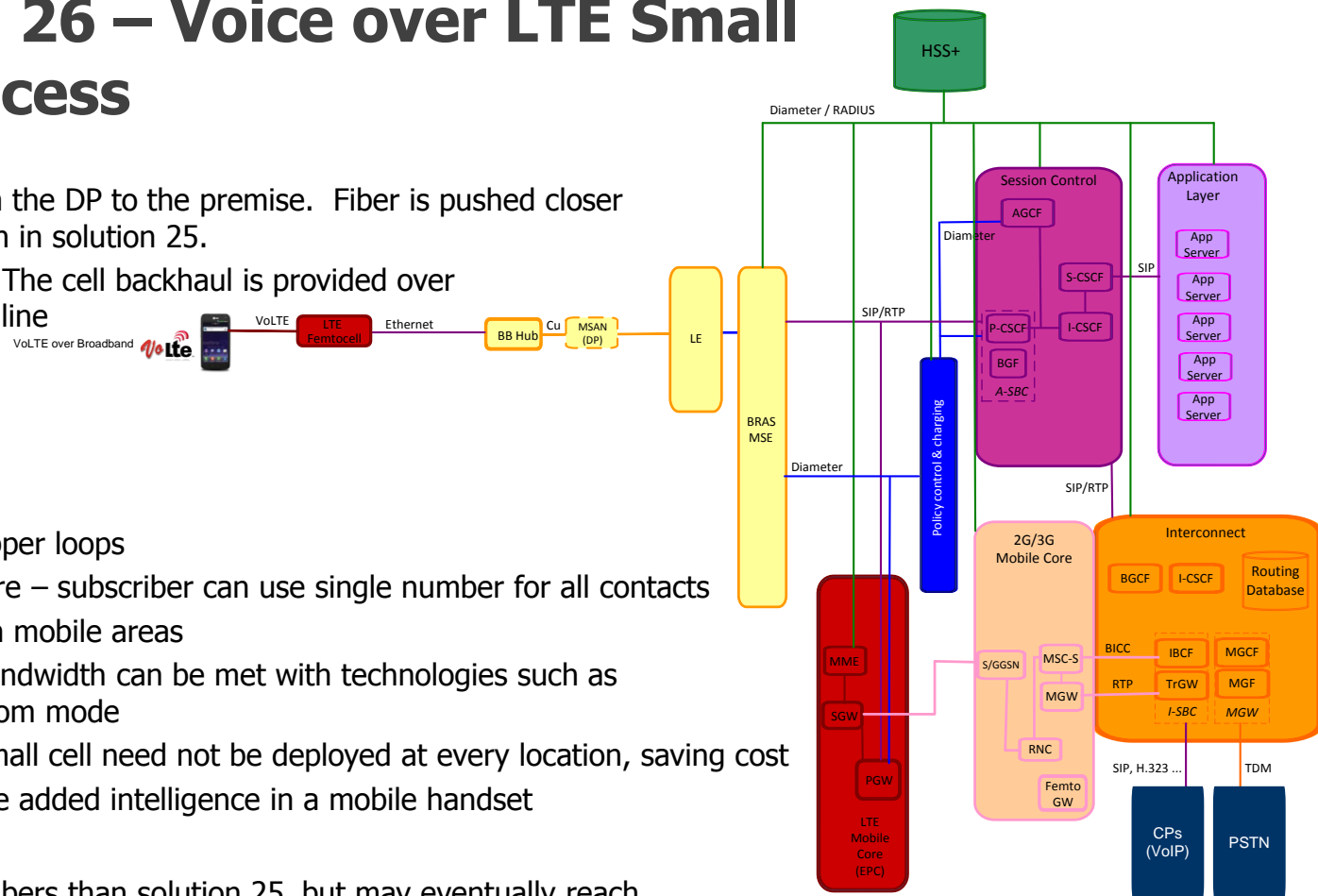
Description:

- The copper loops extend from the cabinet to the premise. Fiber is pushed closer to the subscriber premise than in solution 24.
- An LTE small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
- The subscriber then uses existing VoLTE device for making calls

Pros:

- Leverages part or all of existing copper loops
- Leverages LTE infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Offering reaches more subscribers than solution 24, but may eventually reach bandwidth limitations (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and LTE network infrastructure
- VoLTE handsets are new, early on the technology curve – LTE is a maturing technology

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# Voice Solution 26 – Voice over LTE Small Cell/FTTDP Access

Description:

- The copper loops extend from the DP to the premise. Fiber is pushed closer to the subscriber premise than in solution 25.
- An LTE small cell is deployed. The cell backhaul is provided over the broadband access (xDSL) line
- The subscriber then uses existing VoLTE device for making calls

Pros:

- Leverages part of existing copper loops
- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Initial demands for greater bandwidth can be met with technologies such as bonding, vectoring and phantom mode
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Offering reaches more subscribers than solution 25, but may eventually reach bandwidth limitations (as determined by HSI speeds & femto backhaul reqmts.)
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- As subscriber demands for bandwidth increase beyond what bonding/vectoring/phantom mode/etc. can support, cabinets will need to be deployed, reducing the copper loop lengths and pushing fiber closer to the premise
- Requires subscriber to also be mobile customer and LTE network infrastructure
- VoLTE handsets are new, early on the technology curve – LTE is a maturing technology

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Voice Solution 27 – Voice over LTE Small Cell/FTTP Access

Description:

- The fiber terminates at the subscriber premise (at an ONT)
- An LTE small cell is deployed. The cell backhaul is provided over the broadband access (FTTP) line
- The subscriber then uses existing VoLTE device for making calls

Pros:

- Leverages mobile infrastructure – subscriber can use single number for all contacts
- Subscriber can have service in mobile areas
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Deploying an FTTP solution represents a significant CapEx cost
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- Requires subscriber to also be mobile customer and LTE network infrastructure
- VoLTE handsets are new, early on the technology curve – LTE is a maturing technology

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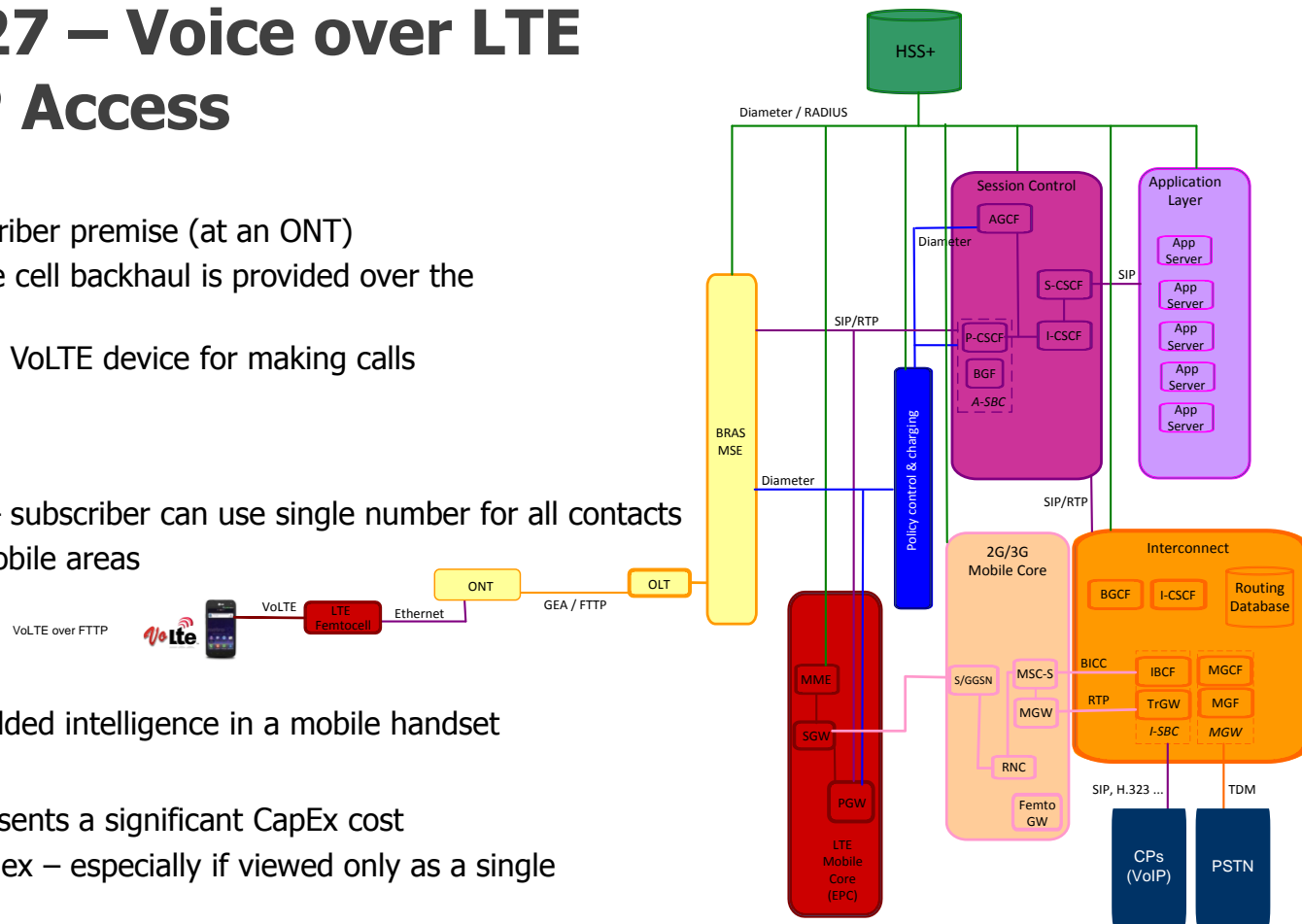
Voice Solution 28 – POTS Emulation over LTE Access

Description:

- Service is provided over an LTE, macro-cellular network
- An ATA connected to an LTE router provides an RJ11 connection for an analog phone

Pros:

- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires full deployment of an LTE network infrastructure
- Requires subscriber to also be a mobile customer
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology

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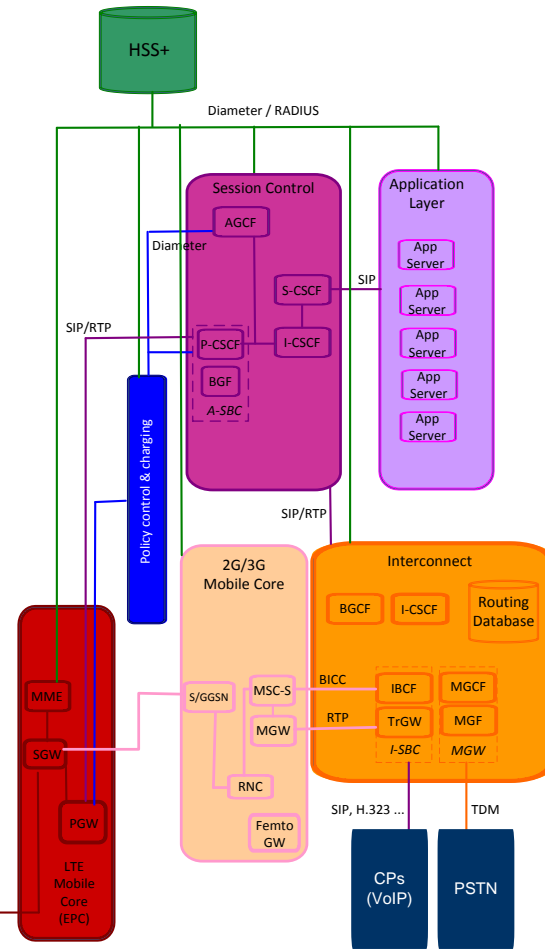
Voice Solution 29 – VoIP using LTE Access

Description:
- Service is provided over an LTE, macro-cellular network
- A VoIP phone is connected to an LTE router
- VoIP phone typically indicates SMB deployments

Pros:
- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- VoIP phones may support additional features beyond an analog line

Cons:
- Requires full deployment of an LTE network infrastructure
- Requires subscriber to also be a mobile customer
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology
- Current cost of a VoIP CPE >> analog phone

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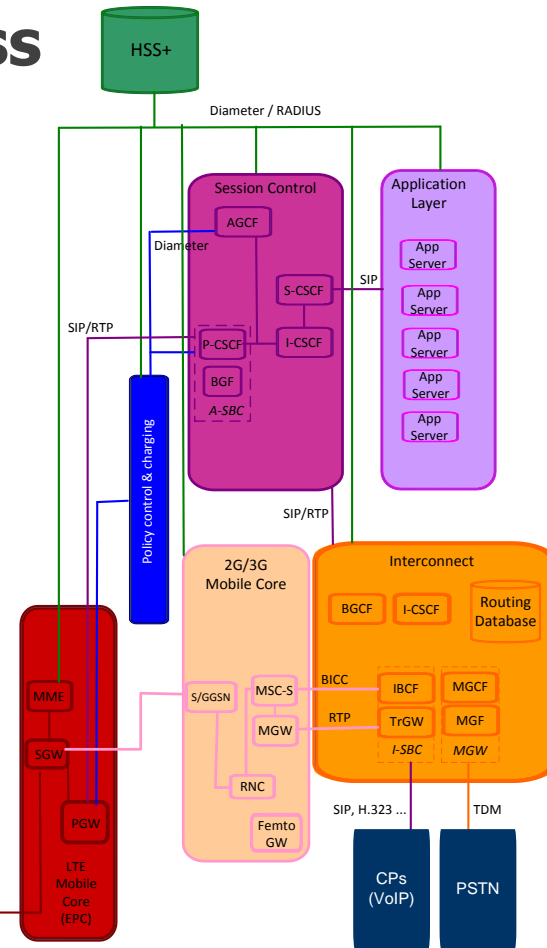
Voice Solution 30 – Voice over LTE

Description:
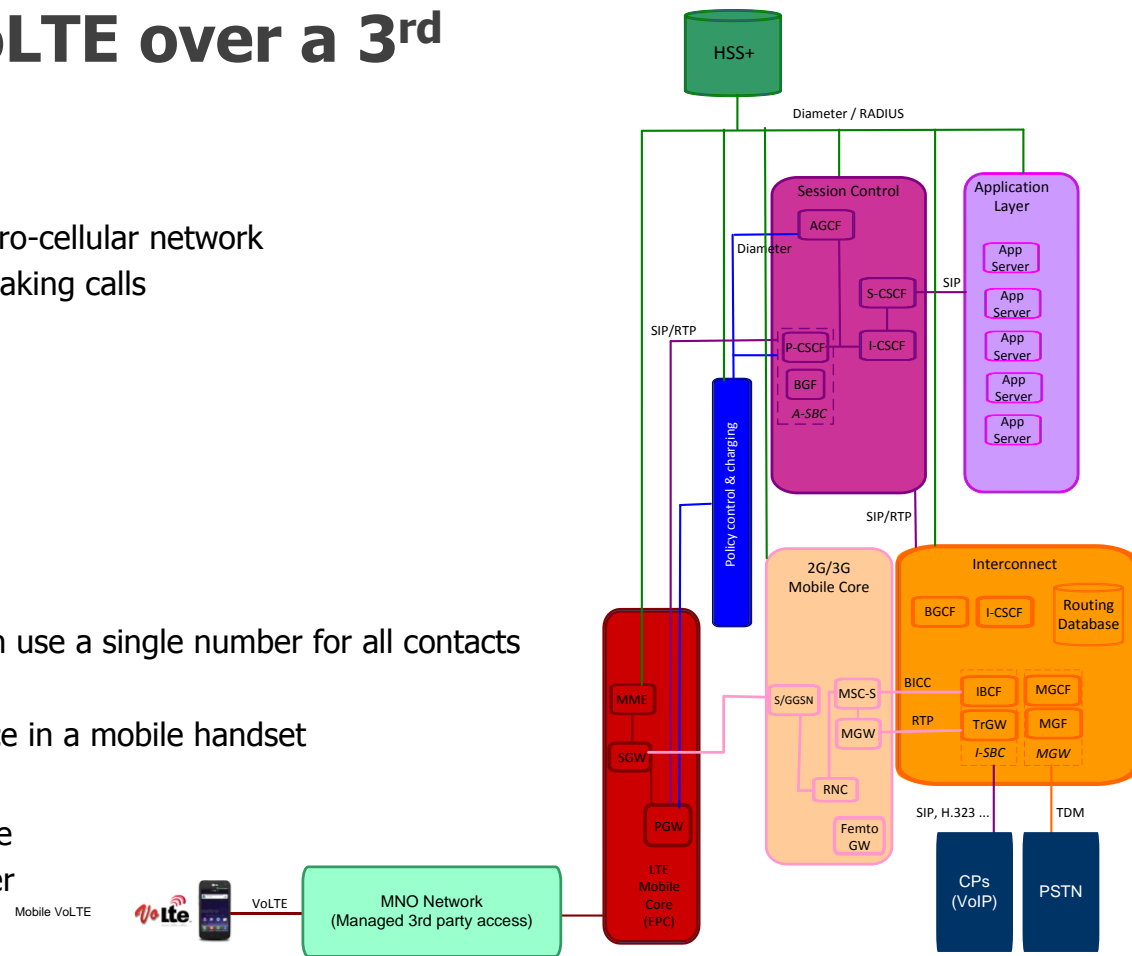- Service is provided over an LTE, macro-cellular network
- The subscriber uses existing VoLTE device for making calls

Pros:
- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- This solution may leverage the added intelligence in a mobile handset

Cons:
- Requires full deployment of an LTE network infrastructure
- Requires subscriber to also be a mobile customer
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology

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Voice Solution 31 – VoLTE over a 3rd Party/MNO

Description:
- Service is provided over a third party's LTE, macro-cellular network
- The subscriber uses existing VoLTE device for making calls

Pros:
- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- This solution may leverage the added intelligence in a mobile handset

Cons:
- Requires agreement with MNO to provide service
- Requires subscriber to also be a mobile customer
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology

HSS+

Diameter / RADIUS

Session Control
AGCF
S-CSCF
I-CSCF
P-CSCF
BGF
A-SBC

Diameter

Application Layer
App Server
App Server
App Server
App Server
App Server

SIP

Policy control & charging

SIP/RTP

SIP/RTP

2G/3G Mobile Core
S/GGSN
MSC-S
MGW
RNC
Femto GW

Interconnect
BGCF
I-CSCF
Routing Database
BICC
IBCF
MGCF
RTP
TrGW
MGF
I-SBC
MGW

MME
SGW
PGW
LTE Mobile Core (EPC)

Mobile VoLTE
VoLTE

VoLTE

MNO Network (Managed 3rd party access)

SIP, H.323 ...
TDM

CPs (VoIP)
PSTN

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Unmanaged Voice Solution 32 – Voice over a Public Wi-Fi Access Point

Description:

- The subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service
- The Wi-Fi service is provided at a public hotspot, which can either be open or limited access
- This is typically a "value add" on top of another primary mode of service. I.e., subscribers using VoWiFi in home or other private networks will likely look to extend the app and utilize while "on the go".
  - Subscribers will likely not use this as a primary form of communication

Pros:

- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, calls can be made from any available Wi-Fi AP
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires subscriber to have possession of Wi-Fi device and app development is needed
- As with any unmanaged solution, the quality of service cannot be guaranteed. If the Wi-Fi network is heavily used, the service quality may be unacceptable
  - Some QoS capabilities may be managed through 802.11e, u and/or proprietary protocols

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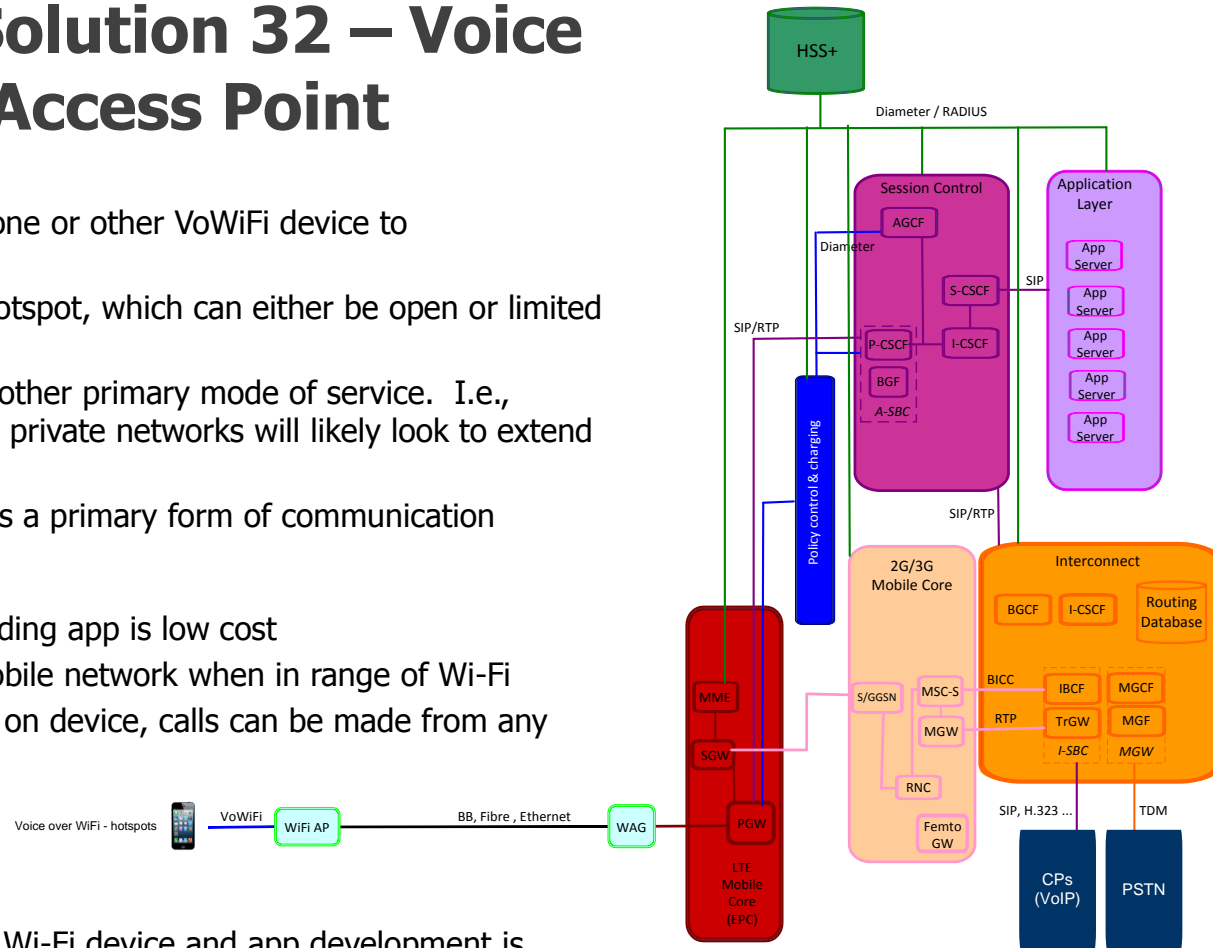
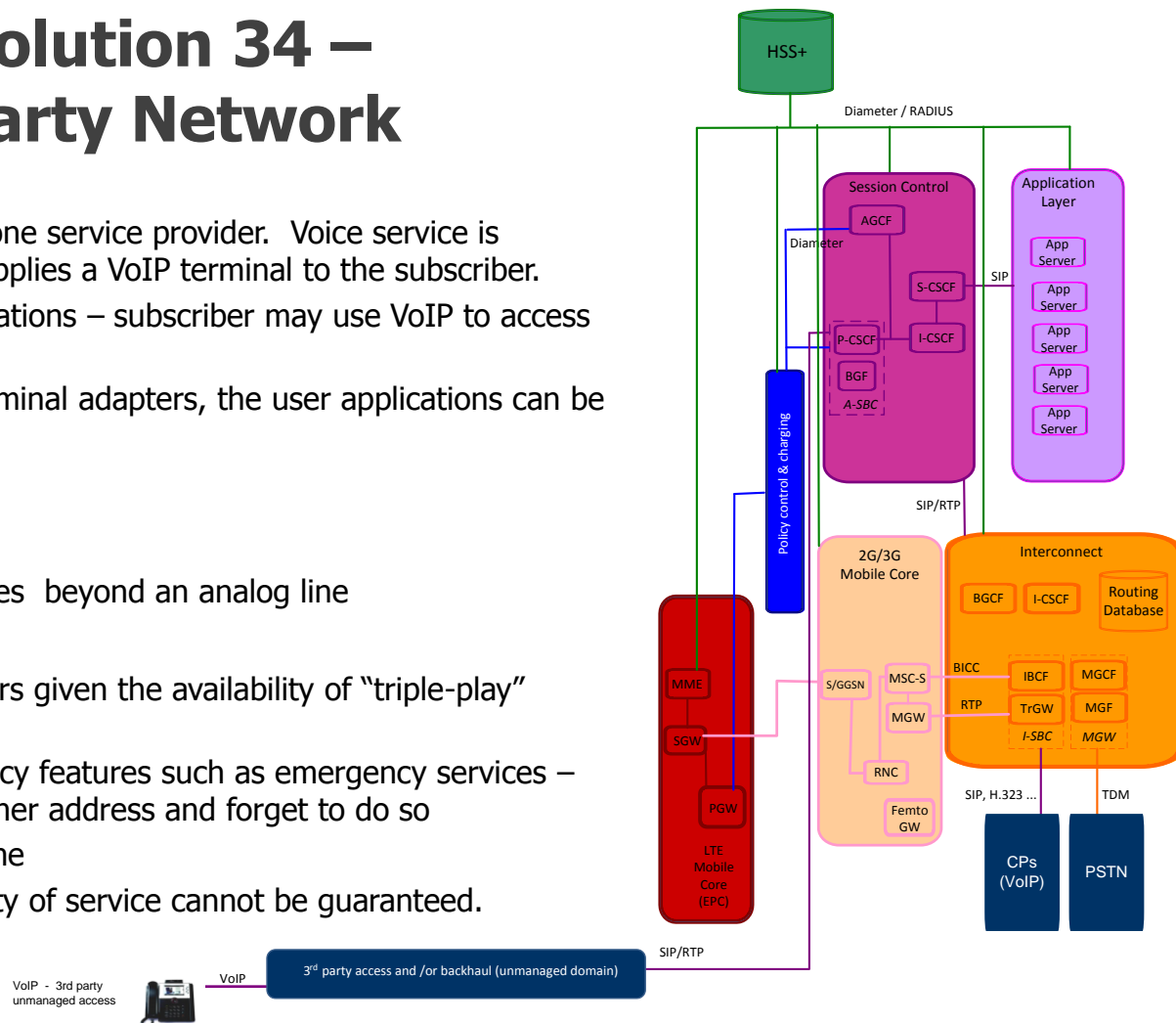# Unmanaged Voice Solution 33 – Over the Top Voice Over IP on a Third Party Network

Description:

- The subscriber purchases BB access from one service provider. Voice service is provided by another party who typically supplies a terminal adapter to the subscriber.
- The typical case is as a "second line", since most BB access providers offer bundles with voice service that are competitively priced

Pros:

- Flexible and cost effective as telephony can be provided over any type of available BB connection
- CPE can be reused

Cons:

- Difficult to differentiate service to customers given the availability of "triple-play" bundles
- Providing power to the ATA may be an issue
- Issues may also exist with some PSTN legacy features such as emergency services – subscriber may be required to register his/her address and forget to do so
- As with any unmanaged solution, the quality of service cannot be guaranteed.

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Unmanaged Voice Solution 34 – VoIP Over a Third Party Network

Description:

- The subscriber purchases BB access from one service provider. Voice service is provided by another party who typically supplies a VoIP terminal to the subscriber.
- One typical case is for "home office" applications – subscriber may use VoIP to access corporate network
- In the cases of softphones or PC based terminal adapters, the user applications can be similar to 33.

Pros:

- In some cases, CPE can be reused
- VoIP phones may support additional features beyond an analog line

Cons:

- Difficult to differentiate service to consumers given the availability of "triple-play" bundles
- Issues may also exist with some PSTN legacy features such as emergency services – subscriber may be required to register his/her address and forget to do so
- Current cost of a VoIP CPE >> analog phone
- As with any unmanaged solution, the quality of service cannot be guaranteed.

Diagram of network architecture including HSS+, Session Control (AGCF, S-CSCF, I-CSCF, P-CSCF, BGF, A-SBC), Application Layer (App Servers), Policy control & charging, LTE Mobile Core (EPC) (MME, SGW, PGW), 2G/3G Mobile Core (S/GGSN, MSC-S, MGW, RNC, Femto GW), Interconnect (BGCF, I-CSCF, Routing Database, IBCF, MGCF, TrGW, MGF, I-SBC, MGW), CPs (VoIP), PSTN, and VoIP 3rd party unmanaged access via 3rd party access and/or backhaul (unmanaged domain).

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Unmanaged Voice Solution 35 – Voice Over Third Party Wi-Fi Access

Description:

- The subscriber uses an app on a smartphone or other VoWiFi device to initiate/terminate voice service
- The Wi-Fi service is provided by an AP that is connected to another BB access service provider for backhaul
- If the Wi-Fi network is private, that part of the call may be "de facto" managed by reducing/eliminating other users from it while calls are made

Pros:

- Can leverage subscriber's CPE device – adding app is low cost
- Allows subscriber to save by bypassing mobile network when in range of Wi-Fi
- Solution enables nomadicity – once app is on device, calls can be made from any available Wi-Fi AP
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires subscriber to have possession of Wi-Fi device and app development is needed
- As with any unmanaged solution, the quality of service cannot be guaranteed. If the Wi-Fi network or BB access are heavily used, the service quality may be unacceptable

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Unmanaged Voice Solution 36 – Voice Over an LTE Small Cell Over A 3rd Party Network

Description:

- An LTE small cell is deployed. The cell backhaul is provided over a third party's broadband access
- The subscriber then uses existing VoLTE device for making calls

Pros:

- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires agreement with MNO to provide service
- Requires subscriber to also be a mobile customer
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- Depending on who offers the voice applications, the value of the service may become diluted across the BB access provider, the MNO and the telephony application provider
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology

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Unmanaged Voice Solution 37 – 2G/3G Small Cell Access Over A 3rd Party Network
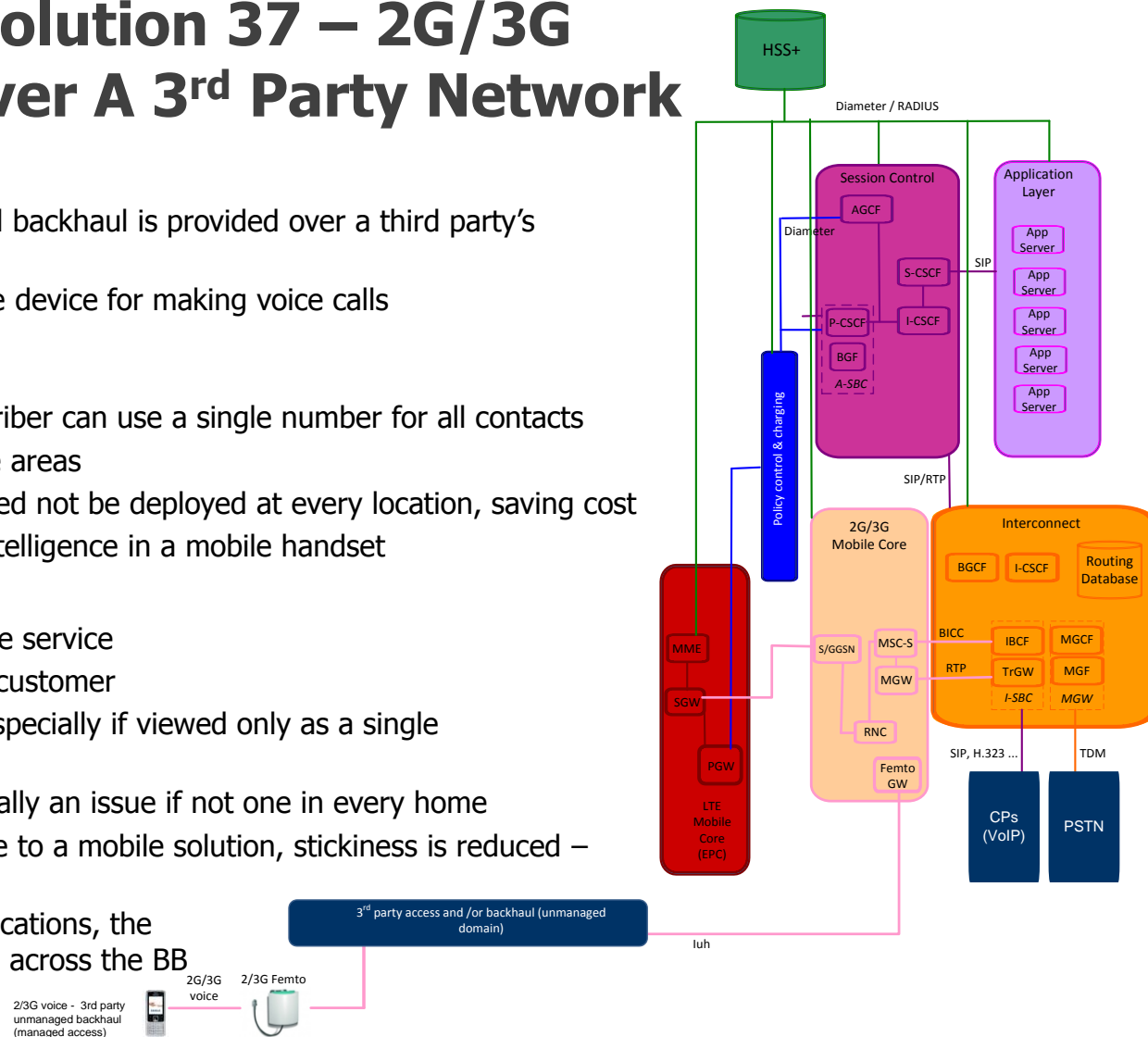
Description:

- An 2G/3G small cell is deployed. The cell backhaul is provided over a third party's broadband access
- The subscriber then uses existing mobile device for making voice calls

Pros:

- Leverages mobile infrastructure – subscriber can use a single number for all contacts
- Subscriber can have service in all mobile areas
- Depending on morphology, small cell need not be deployed at every location, saving cost
- This solution may leverage the added intelligence in a mobile handset

Cons:

- Requires agreement with MNO to provide service
- Requires subscriber to also be a mobile customer
- Solution may be costly and complex – especially if viewed only as a single PSTN/fixed line replacement
- Small cell needs to be powered – especially an issue if not one in every home
- If existing subscriber is forced to migrate to a mobile solution, stickiness is reduced – he/she may switch to competition
- Depending on who offers the voice applications, the value of the service may become diluted across the BB access provider, the MNO and the telephony application provider
- VoLTE terminal equipment is new, early on the technology curve – LTE is a maturing technology

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Examples of Other Service Providers

# Global Service Providers Approach to NGN Voice

- As noted previously, voice network architectures are not "one size fits all". A service provider may take different approaches to serve its subscriber base, e.g.,
  - Terminating the fiber at the LE may be optimal in dense urban settings,
  - Extending fiber to the cabinet or even the DP can be more effective in suburban settings
  - In rural areas, a wireless solution could be most cost effective

- Additionally, service providers may not be able to discriminate between some solutions. For instance if a service provider launches a VoWiFi application, it will likely operate indiscriminately over a private/home network and a public one

- This section provides examples of which service providers are deploying the various technologies

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The Blurring Boundaries of Telecom Service Providers

The boundaries between fixed and mobile will blur as an increasing number of players offer a combination of products.
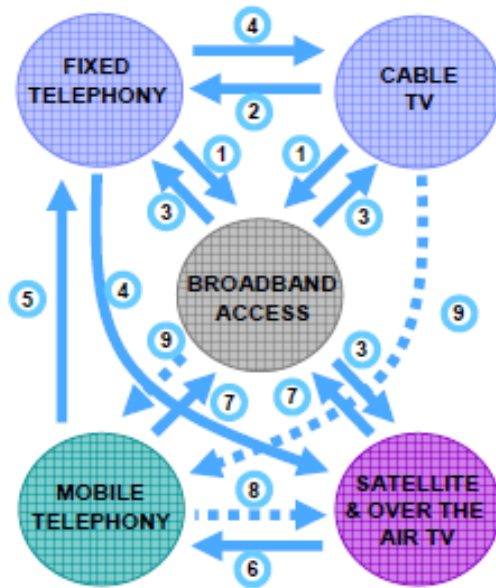
	Description	Examples
1	• DSL and cable modem internet access	wanadoo, kpn, UPC, comcast
2	• Phone service of cable companies	casema, UPC, comcast
3	• Dual and triple play offerings of unbundled carriers	free, TalkTalk, FASTWEB
4	• IPTV and TV content rights acquisition by telecom carriers	belgacom, Telefónica
5	• Fixed Mobile Substitution (« Homezone ») offerings	O2, vodafone, T··Mobile···
6	• MVNO service of TV channels	MOBILE ESPN, M mobile Orange, TF1 mobile
7	• Unbundled or wholesale DSL offerings of mobile and satellite TV providers	vodafone, Sky Broadband, SFR, mobistar
8 / 9	• Mobile TV offerings • Cable TV and DSL quad play offerings through MVNO agreements	Virgin media, SFR tv, SeeMeTV
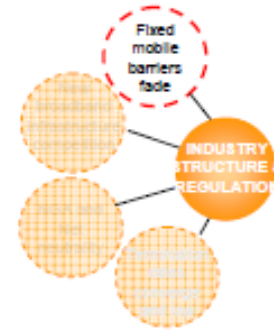
Fixed Mobile Convergence and the noted blurring boundaries are resulting in a merging of the roles and services offered by fixed and mobile operators.

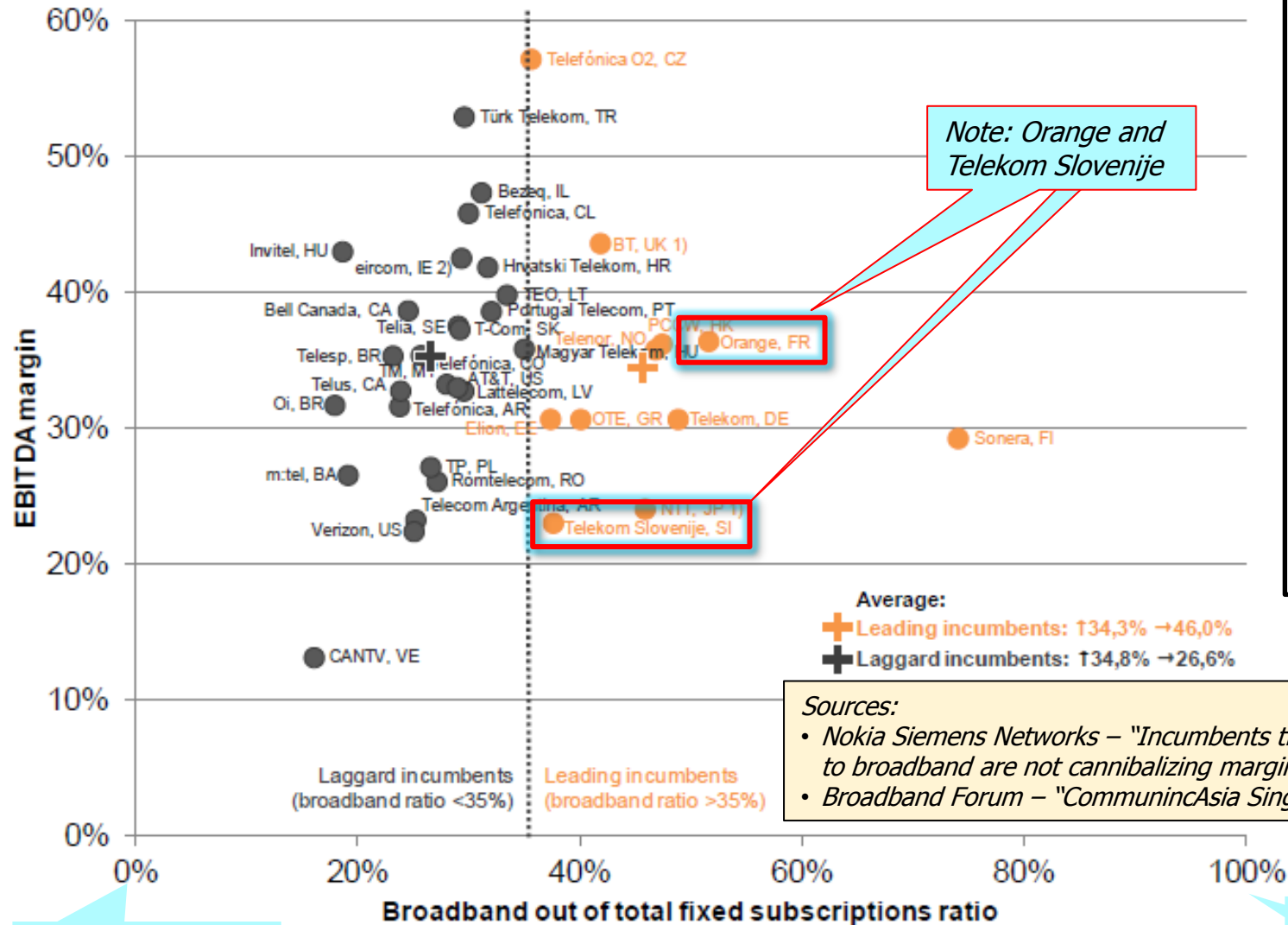*Source: Prampolini, F., IBM – "Telco 2015 – five telling years, four future scenarios" - 2010*

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Examples of POTS over VoIP – Reference List of Service Providers Deploying MSAN

14.8 Million VoIP Lines Served Through Eo2012
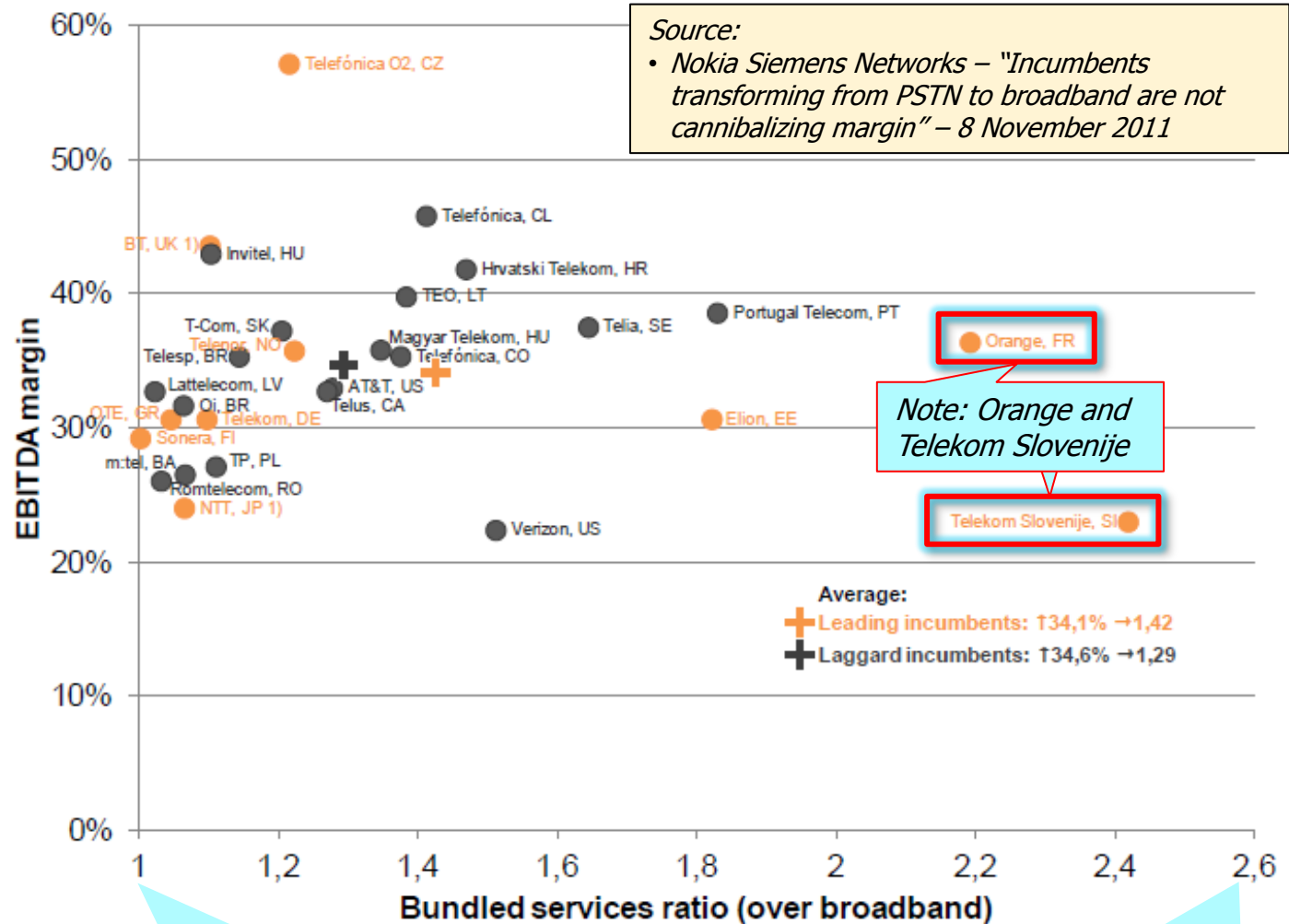**> 50 Service Providers in Total**

Source:
• Alcatel-Lucent Marketing

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Examples of Voice over BB – Service Providers with High Incidence of Broadband

Note: Orange and Telekom Slovenije

Breakdown of Fixed BB Access by Technology – Q1 2012

- DSL
- FTTx
- Cable Modem
- FTTH

Average:
- Leading incumbents: ↑34,3% →46,0%
- Laggard incumbents: ↑34,8% →26,6%

Laggard incumbents (broadband ratio <35%)   Leading incumbents (broadband ratio >35%)

Sources:
- Nokia Siemens Networks – "Incumbents transforming from PSTN to broadband are not cannibalizing margin" – 8 November 2011
- Broadband Forum – "CommunincAsia Singapore" – 20 June 2012

Predominant PSTN

Predominant NGN

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Examples of Voice over Broadband – BB Service Providers with High Incidence of Triple-Play

- Orange (France) and Telekom Slovenije are two examples of predominant broadband service providers with a high incidence of triple play services
  - Orange offers VoIP over ADSL through its Livebox router and service

Source:
- Nokia Siemens Networks – "Incumbents transforming from PSTN to broadband are not cannibalizing margin" – 8 November 2011

Note: Orange and Telekom Slovenije

High Incidence of Single Play

High Incidence of Triple Play

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Additional Examples of Voice over Broadband Offerings

Many fixed access operators are offering voice as part of a BB access bundle. Some additional examples include:

- O_2 Broadband and Home Phone:
  - http://service.o2.co.uk/IQ/SRVS/CGI-BIN/WEBCGI.EXE?New,Kb=Companion,question=ref(User):str(Broadband),T=Broadband_Case,CASE=24539
  - http://www.o2.co.uk/broadband/homephone

- Telecom Italia
  - ADSL e Telefono – http://www.telecomitalia.it/internet/adsl-telefono
  - Ultra Internet Fibra (incl. voice service) – http://www.telecomitalia.it/internet/fibra-ottica

- Telefonica offers "Puesto Integral" and "Puesto Informatico" including ADSL and VoIP*

- KPN – "Internetplusbellen" provides voice and unlimited ADSL in one connection**

> Sources:
> * - MarketLine – "Fixed Line Telecoms in Europe", September 2012
> ** -Lim Shue Ping, S.; "ITU-T Workshop on Next Generation Networks" Hanoi, Vietnam, 15-16 May 2006

- Belgacom:
  - http://www.belgacom.com/be-en/annex_strategy/Str_Consumer.page

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Examples of Termination on VoIP End User Devices

There are various examples of how VoIP clients are used in the industry today

- Mobilkom Austria is using an Internet softphone and IMS core to offer fixed line VoIP service*

- Verizon is using IP end points for its Enterprise-Centrex offering
  - http://www.verizonenterprise.com/resources/presentations/pr_voip-network-architecture-and-call-flows-presentation_en_xg.pdf

- Many VoIP Operators offer PC based Softphone apps as part of an unmanaged "second line". E.g.,
  - Skype
  - Oovoo
  - GoogleTalk
  - Etc.

Verizon VoIP Customer Architecture
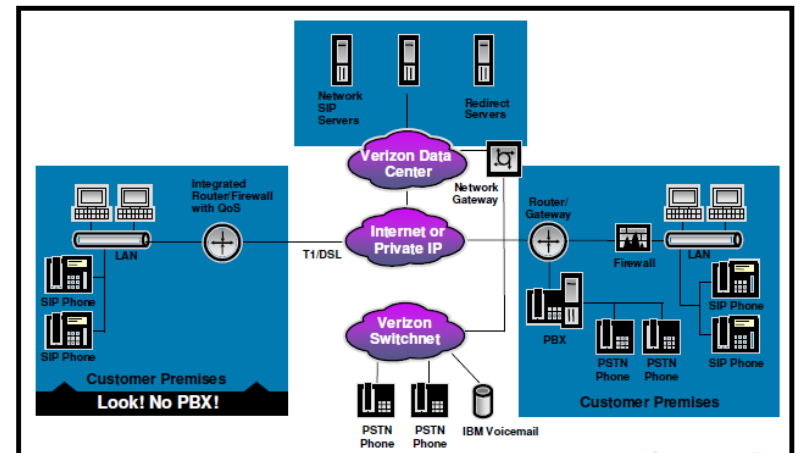
- Source: Infonetics Research– "Service Provider VoIP and IMS Equipment and Subscribers", March 4th, 2013

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Examples of VoWiFi Applications Supported by Service Providers

Service Providers are offering VoWiFi applications allowing users to make, and in some cases receive calls on Smartphones and other Wi-Fi enabled devices.

- Telefonica (Tu Me, Jajah)
  - http://techcrunch.com/2012/05/09/telefonica-tries-its-hand-at-free-calls-texts-with-tu-me-wants-to-take-the-skype-road-to-make-money/
  - http://venturebeat.com/2010/01/07/how-jajah-a-little-phone-company-sold-for-207m-while-everyone-else-got-killed/

- Deutsche Telekom (Bobsled)
  - http://bobsled.com/company/

- Orange (Libon)
  - http://www.libon.com/en/reviews/Opinions-libon-press-blog

- Talktelecom
  - http://www.ciceronetworks.com/cicero-networks-launches-cicero-2-0-vowi-fi-solution-for-fixed-line-operators/

Additionally, many unmanaged voice service providers (e.g., Oovoo, Skype, Viber, etc.) also offer VoWiFi clients for Smartphones

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Examples of 2G/3G Voice as Fixed Line Replacement

- Many subscribers "cutting the cord" and using a mobile phone as their primary source of connectivity – this is resulting in a blurring of the roles between a traditional mobile line and a fixed one.

- As a subscriber "cuts the cord" he/she can take advantage of the mobile nature of 2G/3G service, hence it is not an accurate comparison to a fixed service

- However, various service providers offer home phone fixed line replacement using a fixed wireless terminal (FWT) – this device has an RJ11 jack which can be connected to a traditional fixed handset
    - Vodafone (Spain)
        - http://www.vodafone.es/tienda/particulares/es/internet-y-fijo/telefonia-fija/trae-tu-fijo-a-vodafone/

    - Verizon Wireless – Home Phone Connect
        - http://www.verizonwireless.com/b2c/device/home-connect

    - AT&T – Wireless Home Phone
        - http://www.att.com/esupport/article.jsp?sid=KB413140&cv=820&title=AT#fbid=CcmzrbBP6Kp

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Examples of 2G/3G Small Cell Deployments

Many MNOs are in various stages of offering small cells to supplement 2G/3G macro coverage. Some examples of European service providers offering this to subscribers are noted below:

- Network Norway (Full Coverage) - http://www.thinksmallcell.com/Operators/network-norway.html

- Optimus Portugal (Signal On) – http://www.thinksmallcell.com/Operators/optimus-portugal.html

- SFR France (Neufbox Evolution) - http://www.thinksmallcell.com/Operators/sfr-france.html

- Telefonica Spain (My Mobile Coverage) - http://www.thinksmallcell.com/Operators/telefonica-spain.html

- Vodafone (Access Gateway) - http://www.thinksmallcell.com/Operators/vodafone-uk.html
- Vodafone (Sure Signal) - http://www.thinksmallcell.com/Operators/vodafone-eire.html, http://www.thinksmallcell.com/Operators/vodafone-greece.html,
- Vodafone (Booster) - http://www.thinksmallcell.com/Operators/vodafone-italia.html
- Vodafone (Premium Access for Voice and Data) - http://www.thinksmallcell.com/Operators/vodafone-spain.html

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Examples of VoLTE as Fixed Line Replacement

VoLTE is not as mature as the other technologies presented in this document. Hence the customer use cases for VoLTE are not as prevalent. However, there are existing references to its uptake in the industry.

- Yota (Russia) is moving to LTE as a common infrastructure provider for LTE services. Is currently evaluating three scenarios for VoLTE
  1. Purely a pipe provider, offering QoS to strategic partners
  2. Building pre-IMS solution
  3. Deploying a full IMS core

- "My view is that it (VoLTE) will be a complementary service to strong fixed assets and in combination this will really help boost the customer experience."
  - *Asif Aziz, Group Director Marketing Products and Propositions, Expresso Telecom, Africa (www.telecoms.com)*

- "I think that LTE can be considered as a replacement of fixed lines in general. In some specific areas such as rural regions, where fibre resources are not abundant, or remote areas where FTTx is still a long way from happening, LTE can offer a good and cost effective fixed-line replacement.."
  - *Mohammed AbdelQadir, Director, Mobile Core for Etisalat, UAE (mena.lteconference.com)*

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Examples of LTE Small Cell Deployments

Similar to VoLTE, LTE small cells are not as mature as the other technologies presented in this document and the cases are not as prevalent.

Here are some references to its uptake in the industry:
- Vodafone will begin to deploy the first 3G and LTE small cells throughout its global networks in early 2013
    - *www.gigaom.com, Nov. 13th, 2012*

- NTT DoCoMo readies first dual-mode HSDPA, LTE femtocell for December
    - *www.endgadget.com, Nov. 16th, 2012*

- Verizon Wireless will begin deploying LTE small cells and femtocells sometime in the future to meet growing capacity demands
    - *www.fiercewireless.com, March 5th, 2012*

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Examples of Fixed Line IMS Deployments

The examples below focus on fixed line driven deployments of IMS:

- Deutsche Telekom, France Telecom, KPN, Swisscom and Tele Greenland are all in the process of class 5 replacement with IMS
    - Their customers will be migrated either by:
        - Customers migrating to VoBB, or
        - Back end network simulation

- Slovak Telecom deployed IMS in 2004, has been carrying traffic over it since 2005 and is currently evaluating migration of IPTV to the IMS core

- In China, the fixed line operators are conducting class 5 replacements using IMS
    - China Unicom began in late 2010
    - China Telecom began in early 2011

Additional examples exist in the industry of IMS deployments led by mobile migration or convergence
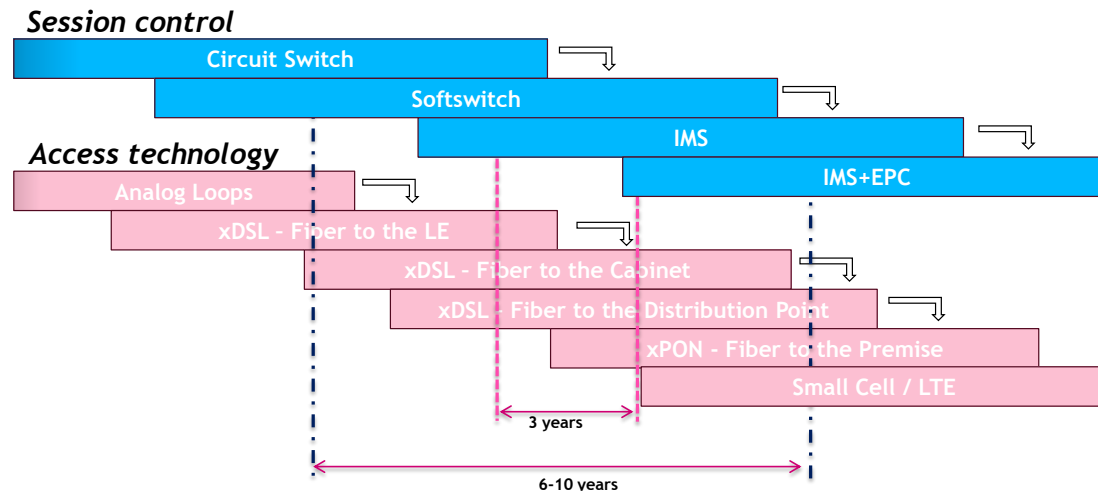
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Bell Labs Observations

Bell Labs Observations – Inclusion of All Network Elements (1 of 9)

- As the NGN network is built for multi-service the resilience for data applications normally included in higher layers (e.g., resend of lost packets, fast re-routing options, etc.) is not enough to provide the voice service quality expected of the PSTN

- Additional components are needed to rapidly re-converge active calls following a failure

- The NGN network must also fully include:
  - Session admission and control functions
  - Subscriber management
  - Support of all interconnecting protocols (signaling and coding)
  - Telephony server software and IN interfaces

- The individual voice solutions included in this deck illustrate how the core network elements must evolve to support the various access technologies

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Bell Labs Observations – Concurrency of Multiple Solutions as Network Evolves (2 of 9)

- It is expected that at any point in time, there will be multiple session control and voice gateway solutions in the network as it evolves
  - The competitive demand for increasing bandwidth and new services require service providers to consistently refresh the network technologies

Session control

| Circuit Switch |
| Softswitch |
| IMS |
| IMS+EPC |

Access technology

| Analog Loops |
| xDSL - Fiber to the LE |
| xDSL - Fiber to the Cabinet |
| xDSL - Fiber to the Distribution Point |
| xPON - Fiber to the Premise |
| Small Cell / LTE |

3 years

6-10 years

- Furthermore, technology solutions are not "one size fits all".
  - One network will concurrently have different solutions depending on factors such as subscriber bandwidth demands, competition, terrain and embedded copper base
  - Service providers may elect to "leapfrog" technology steps depending on specific situations and needs
  - The solutions will depend on underlying technology choices not illustrated in the diagrams (e.g., xDSL may refer to ADSL, VDSL, etc.)
- Concurrent operation of multiple network technologies represents a significant operational complexity and cost to service providers
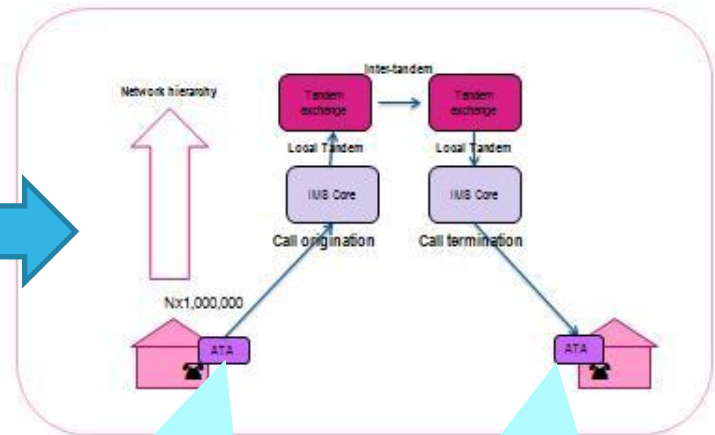
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- The cost model must consider that as fiber moves closer to the user, the access points become correspondingly smaller and more numerous until there is one per household
- As this happens, the softswitch scalability for H.248 is exceeded
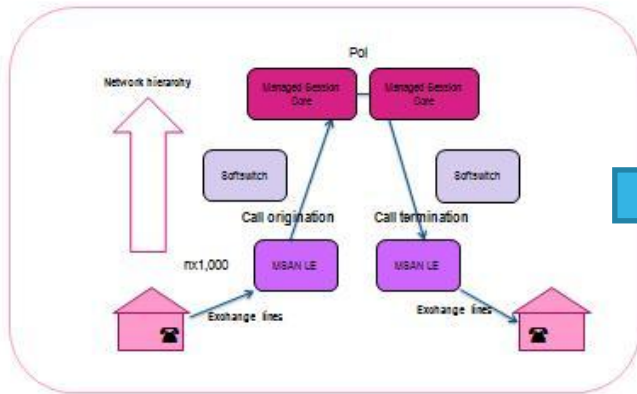
Example scalability limits:
- *"Vendor A" softswitch can support up to 16,000 Trunk Gateways*
- *"Vendor B" softswitch can support up to 1000 Media Gateways*

At some point, H.248 becomes insufficiently scalable to provide service, each endpoint needs a SIP UNI.
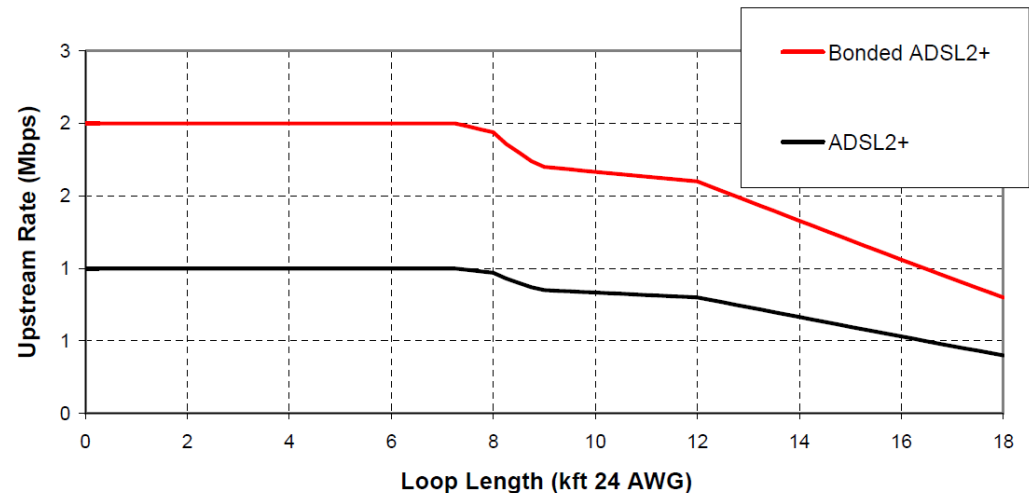
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Bell Labs Observations – xDSL Throughput as a Function of Loop Length (4 of 9)

ADSL2 Downstream - Standard & Bonded

ADSL2 Upstream - Standard & Bonded
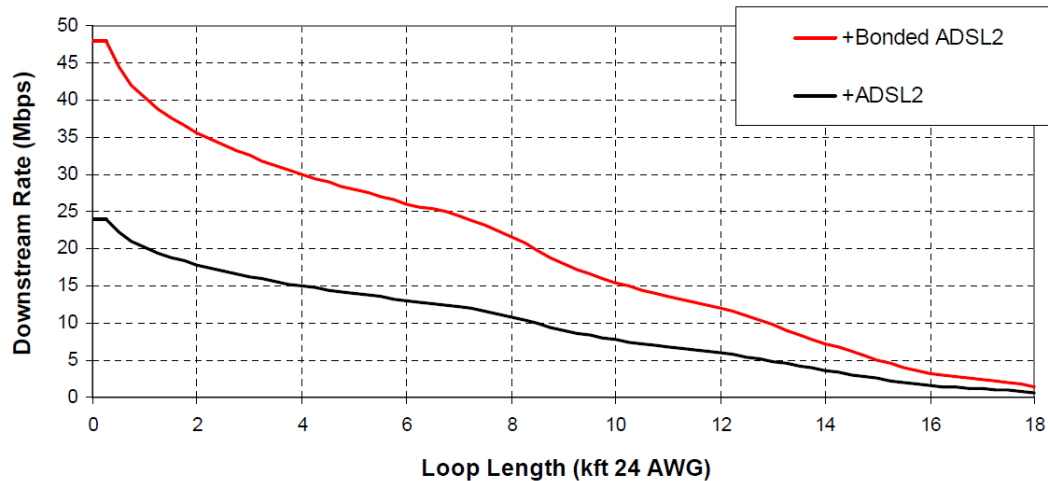
As the subscriber demands for bandwidth increase, fiber must be extended closer to the premise to reduce copper loop lengths and keep up with the demand
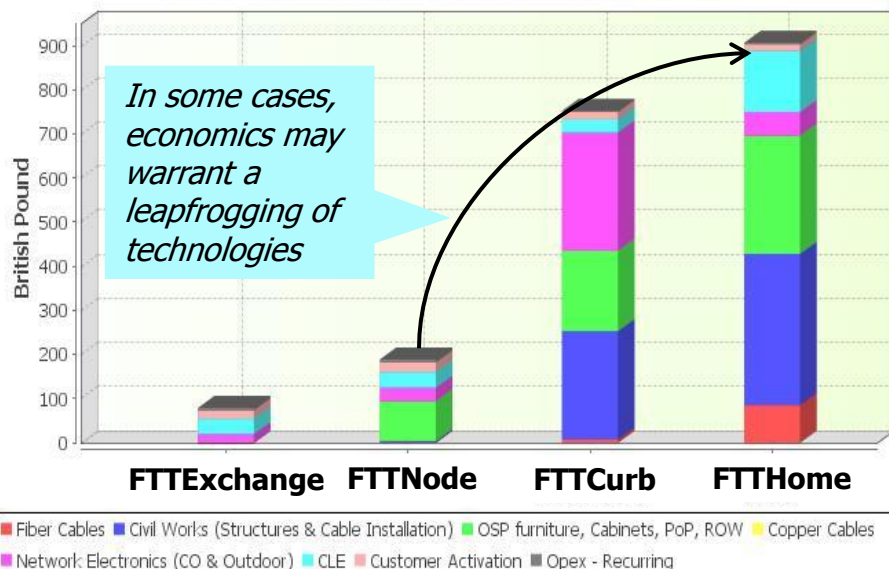
Source: Broadband Forum response to FCC National Broadband Task Force request for information regarding broadband access technology capabilities
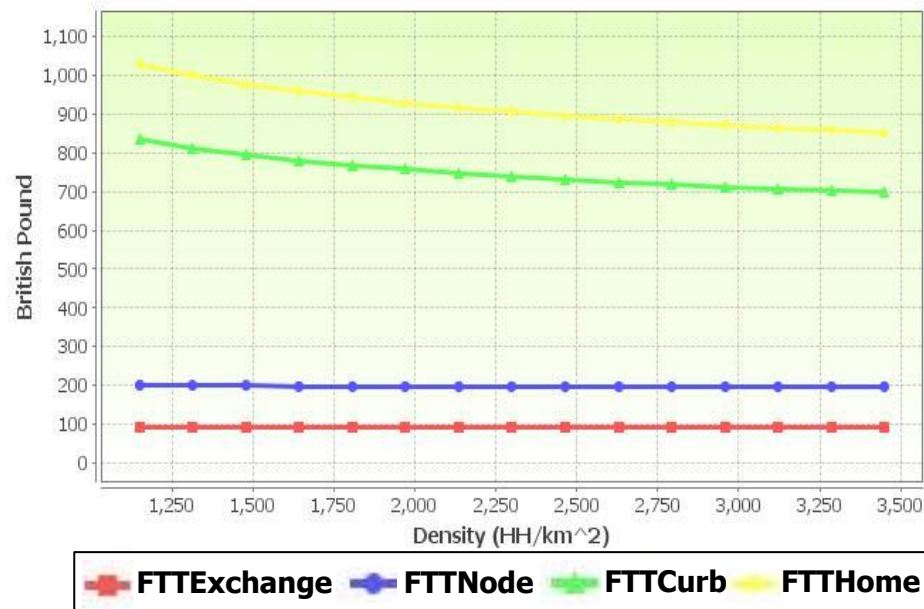
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Bell Labs Observations – Economics of Broadband Access Technologies (5 of 9)

> *However, in an existing network, it is most cost effective to leverage the existing copper plant as much as possible, pushing the fiber out only as far as needed to meet the subscriber's bandwidth demands.*

Access Network TCO per HHC

Legend: FTTExchange · FTTNode · FTTCurb · FTTHome

Access Network TCO per HHC BreakDown

In some cases, economics may warrant a leapfrogging of technologies

FTTExchange, FTTNode, FTTCurb, FTTHome

Legend: Fiber Cables · Civil Works (Structures & Cable Installation) · OSP furniture, Cabinets, PoP, ROW · Copper Cables · Network Electronics (CO & Outdoor) · CLE · Customer Activation · Opex - Recurring

Serving Area Representation	
Population Density (HH/km^2)	2,300
Average CO-DA Loop Length (m)	2,000
Households per Distribution Area (DA)	400
% Single Dwelling Unit vs. Multi-Dwelling Unit	63.0%
Maximum Service Take Rate	60.0%

Source: Bell Labs Hypothetical Model. Actual costs will vary depending on a variety of factors including labor costs, discount rates, condition of terrain, etc.

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Bell Labs Observations – Expansion and Evolution of the Core Network Elements (6 of 9)
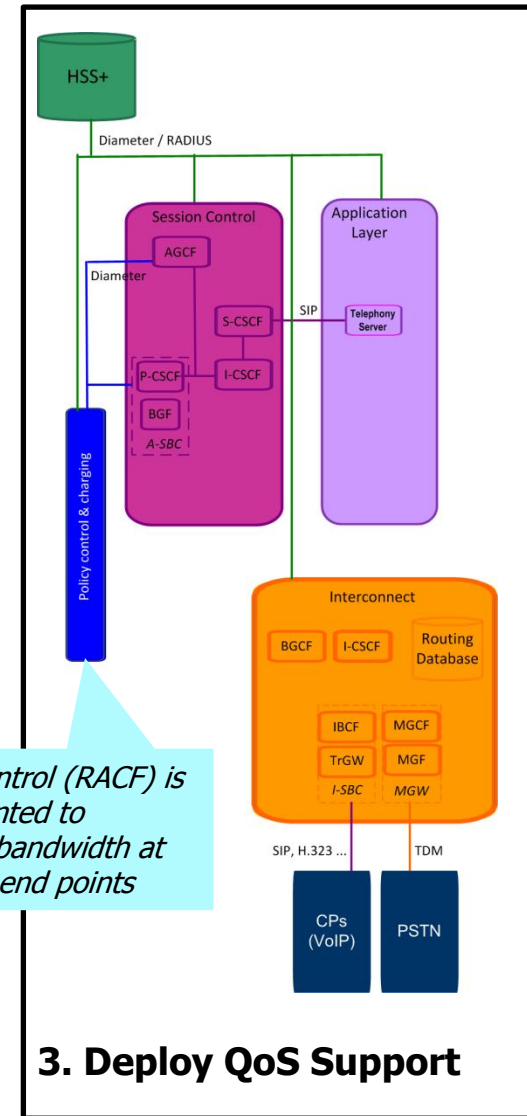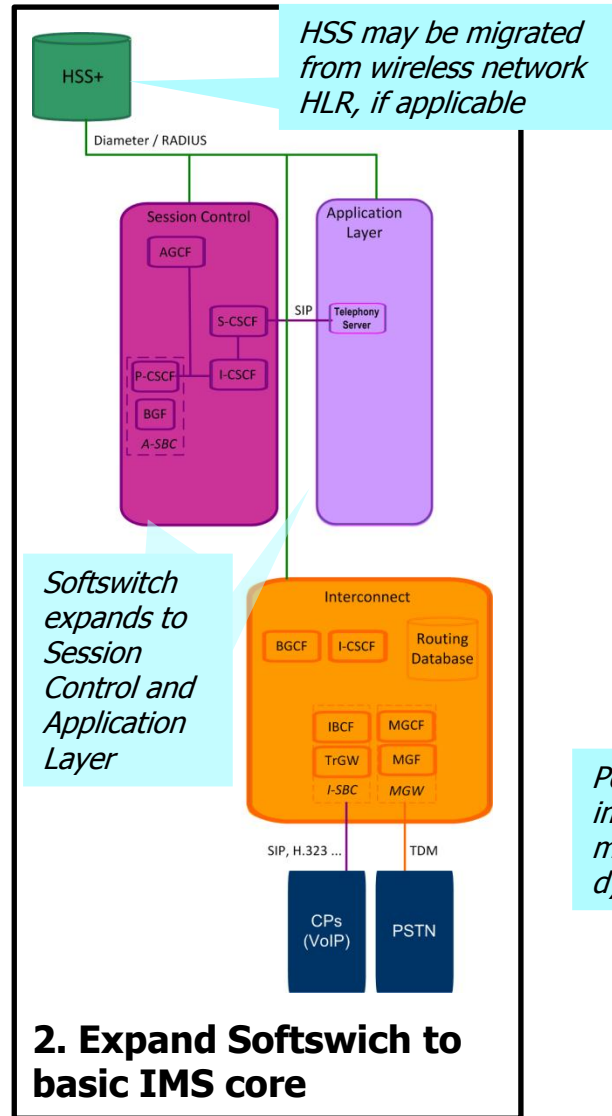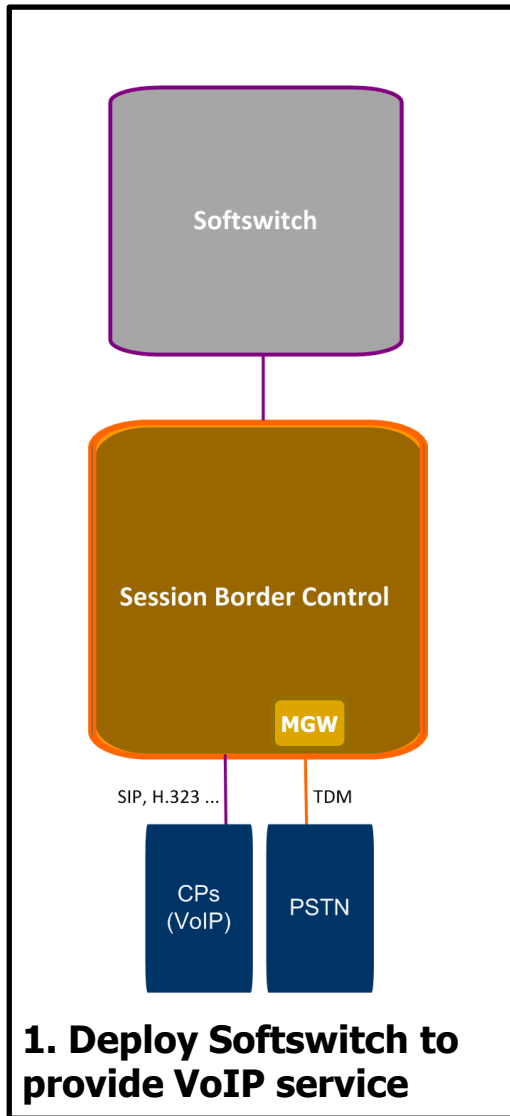
As the number of access technologies providing voice solutions expands, the core network must also grow and evolve to effectively manage it. For instance:

- A softswitch may be used to support basic voice services over an IP network

- As the number of H.248 controlled access gateways grows, a softswitch reaches scalability limitations, requiring that
    - Additional softswitches be deployed, or
    - SIP be introduced as the endpoint control protocol

- As the types of access connections vary and become more complex, the softswitch will evolve to an IMS core, which is more effective to:
    - Facilitate dynamic allocation of bandwidth for voice over shared access resources
    - Deploy and support complex services

- A 2G/3G mobile core is needed to support 2G/3G access

- An EPC is needed as LTE is introduced

- As the network needs to interconnect to more peer IP networks, the number of signaling and coding protocols must be expanded to cover all interworking scenarios

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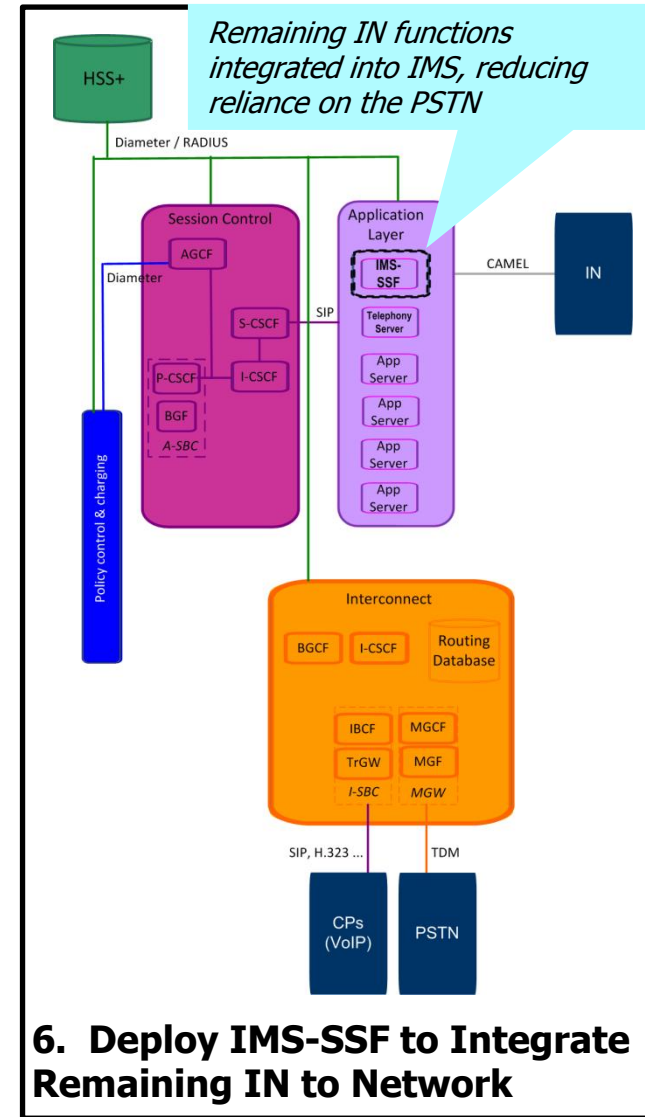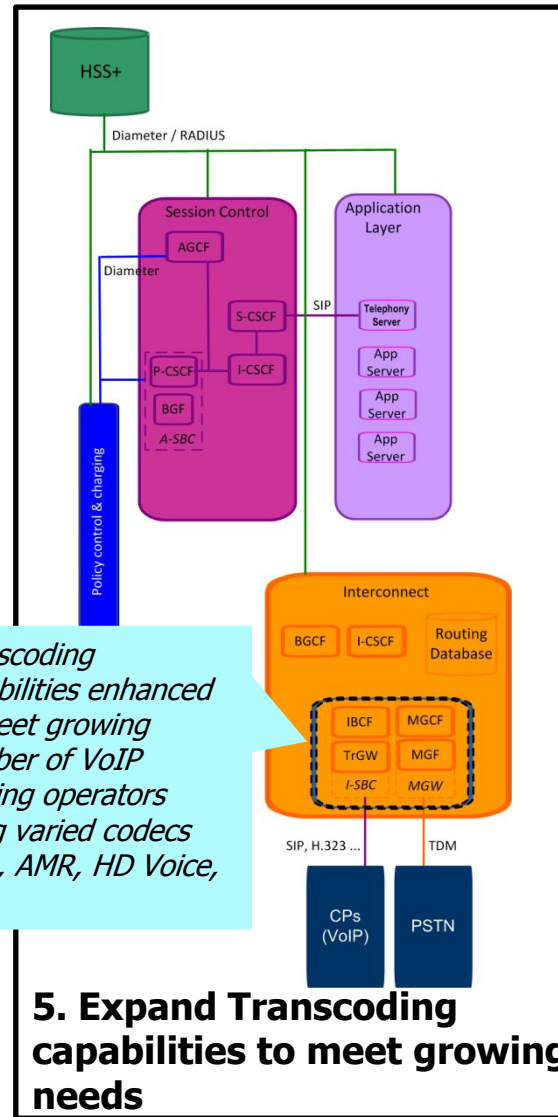- The evolution of a Softswitch based call control network to an IMS core can occur gradually over several phases

- A set of illustrative migration steps are shown in the following slides.

- The actual steps followed by a service provider will depend on a variety of conditions, such as the softswitch in service, mix of access technologies, services offered, competitive environment, etc.

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1. Deploy Softswitch to provide VoIP service

2. Expand Softswich to basic IMS core

3. Deploy QoS Support

HSS may be migrated from wireless network HLR, if applicable

Softswitch expands to Session Control and Application Layer

Policy control (RACF) is implemented to manage bandwidth at dynamic end points

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Additional application servers support value add, revenue generating services

Remaining IN functions integrated into IMS, reducing reliance on the PSTN

Transcoding capabilities enhanced to meet growing number of VoIP peering operators using varied codecs (e.g., AMR, HD Voice, etc.)

4. Deploy Additional Application Servers for VAS

5. Expand Transcoding capabilities to meet growing needs

6. Deploy IMS-SSF to Integrate Remaining IN to Network

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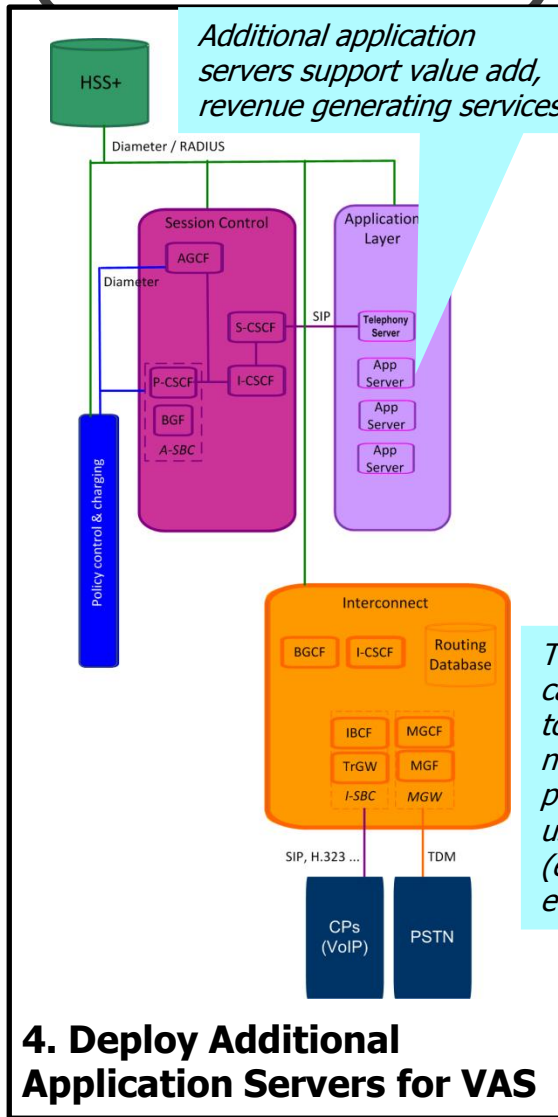
- Both the cost as well as the noticeable quality of a voice call can be quite different between a managed voice service and an unmanaged one.
  - Managed voice assures QoS and an expected level of service. It represents the MEA equivalent of PSTN voice
  - There is an incremental cost associated with managing these sessions on a network
  - Unmanaged voice does not assure such quality. It is provided at a "best effort" grade which may be inferior quality. Hence it incurs a lower network cost.

- There are a growing number of alternatives for terminating voice calls – the POTS "black phone" is no longer the only option
- A UK based E.164 number can now be mapped to a managed or unmanaged service (such as Skype or Google Talk) and can terminate anywhere in the world
- Likewise, non-UK E.164 numbers can also terminate in the UK

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- In this analysis 37 different scenarios for providing voice service over a next generation network were evaluated.

- Each scenario has a set of inherent characteristics that define a specific user experience. For example:
  - Voice Quality – MOS
  - Value added features and services
  - Emergency services
  - Mobility/Nomadicity – range of coverage
  - The ability to make calls, receive calls or both

- The relative value of a specific scenario, compared to the others depends on the individual subscriber's expectations and needs.
  - E.g., some users may view the transition from PSTN to mobile an upgrade while others may see it as a downgrade

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Bell Labs Observations – Categorizing the Different Voice Architectures (9 of 9)

- The differences between the 37 identified solutions in terms of cost and subscriber experience vary widely. Some are extremely different while others have similarities.

- The user experience has a subjective element to it – hence it is difficult to definitively categorize all solutions.

- Each solution may also have elements that are shared with other applications such as mobility and data, hence the network cost cannot be fully allocated to fixed voice

- As a reference, the following table categorizes each of the 31 managed voice solutions in terms of:
  - The fiber termination point – as this is a key component to the cost, and
  - The connection at the user premise (analog, VoIP, VoWiFi or mobile) – which will impact the user experience

	FTT SP building	FTT Cabinet	FTT DP	FTT Premise
Analog	1, 28	2	3	13
VoIP	4, 7, 29	5, 8	6, 9	14, 15, 16
VoWiFi	10	11	12	17
Mobile	18, 22, 23, 24, 30, 31	19, 25	20, 26	21, 27

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Conclusions

Conclusions – Accounting for the User Experience

- While some of the solutions may have some commonalities, there are enough differences between each so that one uniform cost model cannot adequately represent all the alternatives

- The voice quality also varies, with today's mobile solutions normally providing a quality inferior to the PSTN/POTS.
  - As services/codecs such as HD voice and AMR-WB become more used, voice quality may also be more accepted as a premium differentiator.

- Most operators now treat mobile networks differently with respect to tariffs and interconnect charges.
  - Many of the VoIP and VoWiFi solutions also introduce nomadicity to varying degrees, which some users may consider at a premium.

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Conclusions – Elements to Include in a Modern Equivalent Asset Model

A PSTN modern equivalent asset model should contain a comprehensive set of components ensuring that all elements of the network are included accordingly

1. All the network elements required to provide the subscriber management, session control, telephony features, bandwidth, QoS and resilience needed for the managed voice service should be included

2. The multiple architectural alternatives that may occur concurrently should all be included accordingly. They should also include:
   - Migration costs as the technology evolves
   - Escalating OpEx as a growing number of solutions must all be maintained
   - The complexity cost of interworking the multiple solutions, which grows at an exponential order of magnitude and the number of solutions expands.

3. When comparing modern NGN based service to PSTN quality voice, the above points should be accounted for and only the managed voice solutions should be included in the model
   - Unmanaged voice should be excluded as it does not include all the above elements

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Conclusions – Elements to Include in a Modern Equivalent Asset Model (Cont'd)

It is important to carefully choose the scope of an NGN-Modern Equivalent Asset (MEA) model for PSTN Voice

- If the model is too restrictive – it drives to a conclusion that voice solutions 1, 2 and 3 are the only modern equivalents of PSTN service.
  - This is an extremely restrictive view and will not represent the largest majority of next-gen voice traffic

- On the other hand, if the model is too inclusive, it will include too many solutions, some of which are not "apples-to-apples" comparisons to PSTN voice.
  - It may include calls that:
    - Have noticeably lower quality,
    - Terminate on PCs, game consoles or other devices, and
    - May even terminate at points outside the UK

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Contributors

The author wishes to acknowledge and thank several individuals who enabled this analysis and made it a rewarding experience.

- **Alan Nunn** of BT for co-ordinating the work related to this track and hosting the 3-day workshop for review and discussion of architectures and PSTN features
- **Maria Cuevas** for contribution of the architectural diagrams that we used as the basis of the solutions analyzed in this document.
- Also, thanks to Maria, **Ian Jenkins** and **Adam MacGill** for their active participation in the workshop

The author would also like to acknowledge the contributions of **Kathy Romano** and **John Schaefer** of Bell Labs for their research into global service providers strategies for providing voice services

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Glossary of Acronyms

- ADSL - Asymmetric Digital Subscriber Line
- AGCF – Access Gateway Control Function
- AMR-WB – Adaptive Multi-Rate–Wideband
- AP – Access Point
- A-SBC – Access Session Border Controller
- ATA – Analog Terminal Adapter
- BB – Broadband
- BGCF – Breakout Gateway Control Function
- BICC – Bearer Independent Call Control
- BRAS – Broadband Remote Access Server
- BSC – Base Station Controller
- CapEx – Capital Expenses
- CPE – Customer Premise Equipment
- DP – Distribution Point
- DSL – Digital Subscriber Line
- DSLAM – DSL Access Modem
- EPC – Evolved Packet Core
- FCC – Federal Communications Commission
- Femtocell – Small Cells (Used in mobile networks)
- FTTP – Fiber to the Premise
- FTTx – Fiber to the "x" (Curb, Neighborhood, etc.)
- FVA – Fiber Voice Access
- FWT – Fixed Wireless Terminal
- GEA – Generic Ethernet Access
- GGSN – Gateway GPRS Support Node
- GPRS – General Packet Radio Service
- GW – Gateway
- HSI – High Speed Internet
- HLR – Home Location Register

- HSS – Home Subscriber Server
- IBCF – Interconnection Border Control Function
- I-CSCF – Interrogating Call Session Control Function
- IMS – IP Multimedia System
- IMS-SSF – IP Multimedia Service Switching Function
- IN – Intelligent Network
- IP – Internet Protocol
- I-SBC – Interconnect Session Border Controller
- LE – Local Exchange
- LTE – Long Term Evolution (4G mobile technology)
- MGCF – Media Gateway Control Function
- MGF – Media Gateway Function
- MGW – Media Gateway
- MME – Mobility Management Entity
- MNO – Mobile Network Operator
- MOS – Mean Opinion Score
- MSAN – Multi-Service Access Node
- MSC-S – Mobile Switching Center Server
- MSE – Multi-Service Edge
- MSO – Multi-System Operator
- MVNO – Mobile Virtual Network Operator
- NGN – Next Generation Network
- OLT – Optical Line Terminal
- ONT – Optical Network Terminal
- OpEx – Operational Expenses
- OTT – Over the Top
- PC – Personal Computer
- P-CSCF – Proxy Call Session Control

Function
- PGW – Packet Data Network Gateway
- PLT – Power Line Transmission
- PON – Passive Optical Network
- POTS – Plain Old Telephone Service
- PSTN – Public Switched Telephone Network
- QoS – Quality of Service
- RACF – Resource and Admission Control Function
- RADIUS - Remote Authentication Dial Up Service
- RJ11 – Registered Jack 11 (Standard Telephone Jack)
- RNC – Radio Network Controller
- RTP – Real-time Transport Protocol
- S-CSCF – Serving Call Session Control Function
- SGSN – Serving GPRS Support Node
- SGW – Signaling Gateway
- SIP – Session Initiation Protocol
- SMB – Small or Medium Businesses
- TDM – Time Division Multiplexing
- TrGW – Translation Gateway
- UNI – User Network Interface
- VAS – Value Added Services
- VDSL – Very-high-bit-rate Digital Subscriber Line
- VoBB – Voice over Broadband
- VoIP – Voice over IP
- VoLTE – Voice over LTE
- VoWiFi – Voice over Wi-Fi
- WAG – Wi-Fi Access Gateway

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