Cologne Chip

CPE Solutions

for Converged Networks and Next Generation Networks

from an ISDN Point of View

White Paper ✦ October 2010

Cologne Chip AG
Eintrachtstrasse 113
D - 50668 Köln

Germany
Tel.: +49 (0) 221 / 91 24-0
Fax: +49 (0) 221 / 91 24-100

http://www.CologneChip.com
http://www.CologneChip.de
support@CologneChip.com

1 About this White Paper and about the Company

This document is intended for electronic engineers and product managers that are involved in the design of xDSL modems with built-in VoIP router functionality.

In this White Paper, the team of Cologne Chip is pleased to explain about the technical aspects for the design of such *Integrated Access Devices (IADs)* that result from the ISDN market situation in Western Europe. The document includes a brief introduction of the ISDN technology and the terminology. Reading this paper will give you an insight to the telephony infrastructure in private homes and small companies with a special focus on the German market. You will understand why ISDN connectivity is requested by European *Internet service providers (ISPs)* and *telephone companies (Telcos)* when sourcing equipment for *Voice / Data Convergence* and for *Next Generation Networks (NGNs)*. Furthermore, this document is intended as a starting point for the hardware and software conception of IADs with integrated ISDN ports.

IAD
ISP
Telco
NGN

Cologne Chip is manufacturer of ISDN chips and takes a leading position in the world market. The company is based in Germany –the country where ISDN was invented– and has been in the ISDN business for more than 15 years. The Support team of Cologne Chip has accompanied a large number of VoIP gateway and IAD designs, so there is a broad experience in this field of applications. As an electronic engineer, you are kindly invited to benefit from this expertise by discussing with our Support team about new projects from scratch – an in-depth discussion in terms of both, hardware and software architecture.

In this regard, Cologne Chip can be more than a chip-set supplier, more than just a business partner – we would like to become your fellow engineers teaming up for fast time-to-market.

2 ISDN Basics and the Market Situation in Germany

ISDN

ISDN (Integrated Services Digital Network), formerly known as '*Integrated Speech and Data Net*', is a digital, circuit-switched telephone network system that is widely used in Europe, especially in Germany and in its neighbouring countries.

In private homes in Germany there is a high ISDN penetration: The rate of ISDN subscribers comes close to the rate of analog POTS users. In companies the ISDN penetration reaches almost 100 percent.

B-channels

Introduced in the 1980s, ISDN was the first kind of xDSL technology using digital transmission methods to carry more than one voice channel over the 'last mile'. The existing pair of copper wires between the Central Office and the subscriber's premises are utilized to achieve a net data rate of 144 kbit/second. This is enough bandwidth to offer two *bearer channels (B-channels)* with 64 kbit/second each which is equivalent to a 3.4 kHz voice channel at 8 ksamples/second. So ISDN subscribers can e.g. perform two phone calls at the same time (e.g. parents and children phoning their friends) or surf the Internet at 64 kbaud and phone simultaneously.

In some market studies, not the number of subscribers is shown but the number of voice channels. So –as ISDN offers two channels– the ISDN penetration even exceeds the number of analog POTS lines in Germany (see Figure 1).

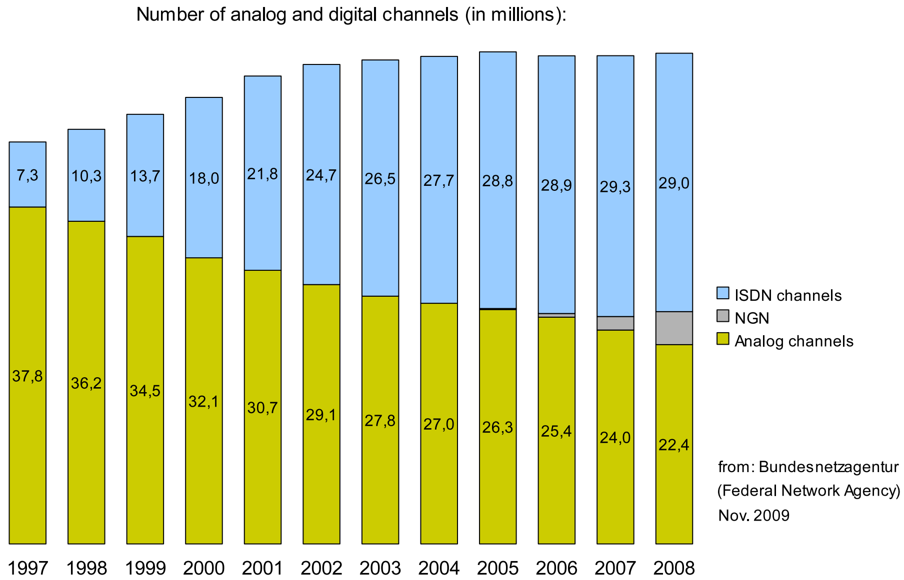

Figure 1: *ISDN penetration in Germany*

FttH

With 64 kbaud, the data rate of an ISDN B-channel is good enough for narrow-band data communications, too. ISDN was the leading technology for Internet access in the 90s. Nowadays it is still used by a significant number of Internet users in Germany. They either have not yet upgraded to broadband or simply have no access to a copper-bound technology like ADSL: As a result of the early fiber-rollout of Deutsche Telekom in the 90th many people in the eastern part of Germany 'suffer' from special fiber optic installations for PSTN services only without any access to modern FttH technologies (Fiber-to-the-Home).

D-channel

Subtracting the bandwidth of the two B-channel (2×64 kbaud) from the total ISDN bandwidth of 144 kbaud, the remaining 16 kbaud are used for a *signalling channel (D-channel)* for the communication with the Public Switch. Digital signalling allows the implementation of sophisticated services in the telephone network: E.g. users can easily initiate 3-party conference calls menu-driven on the LCD screen of their digital feature-phone. As the D-channel is used for the signalling information, no DTMF tones have to be send. No data on the bearer channels is touched for any signalling information. Status information can be exchanged by an ISDN phone with the Public Switch without establishing a phone call.

D-channel protocol
E-DSS1

The D-channel signalling has been standardized in a *D-channel protocol*, called *E-DSS1 (European Digital Signalling System #1)*. Although there are still some old national D-channel protocols left in some parts of the world, E-DDS1 is the predominant signalling standard. We will get back to the D-channel protocol later on when we have a look at the required software for an IAD project.

BRI
PRI
E1, S_{2M}

There are two types of ISDN services: *Basic Rate Interface (BRI)* and *Primary Rate Interface (PRI)*. This document deals with the BRI standard which offers two B-channels. In contrast to BRI, the PRI standard provides 30 B-channels summing up to a total data rate of 2,048 kbaud but it is not that widely spread in Germany: Due to the fact that Telcos charge quite high monthly subscription fees for a PRI line, it is used in larger companies only. PRI is also known in Europe under the acronyms *E1* or S_{2M}.

CPE
SMB
SoHo

Anyway, this White Paper focuses on devices for the *CPE* market *(Customer Premises Equipment)* for the use by consumers and –at a glance– for *SMB* applications *(Small / Medium Businesses)*. In consumer and *SoHo (Small office / Home office)* applications as well as SMB applications, BRI is predominant.

An IAD with analog POTS support must be considered as entry-level CPE for consumers only, while the ISDN version targets both customer groups, consumers and SoHo: Even most private ISDN subscribers have such feature-rich telephony equipment that is equivalent to SoHo-style equipment. Furthermore, it is common in German homes to own a small PABX system – except in single occupancy flats of course. As a consequence, the required feature set in an IAD for the consumer market and for SoHo users is very similar.

xDSL
ADSL2+
VDSL2

As the ISDN penetration in private homes and small companies is high, ISPs and Telcos prefer to have *one version of an IAD only* for private consumers *and* SoHo customers. The service providers enjoy the logistical benefits of an universal IAD. Such a device must support xDSL (typically ADSL2+) on top of analog POTS as well as on top of ISDN (known as 'ADSL over ISDN or 'Annex B"). Due to the demand for higher bandwidth, some Telcos (e.g. Deutsche Telekom) nowadays focus on VDSL2 instead of ADSL2+.

SDSL

For SMB applications, VoIP gateways usually support several ISDN BRI lines. For enterprise applications, VoIP gateways come with one or several PRI ports instead of BRI. Nowadays, such professional IADs are often based on SDSL technology.

In 2005 the transition process from circuit-switched networks to next generation networks began in Germany. It can be seen in the statistics (Figures 1 and 2). Despite that fact that ISDN is not used anymore on the last mile as access technology, the IADs in a NGN usually provide internal ISDN ports so that subscribers can connect their existing ISDN terminal equipment. So, by the success of NGN installations, even many of the former analog subscribers nowadays are in a position to use ISDN equipment.

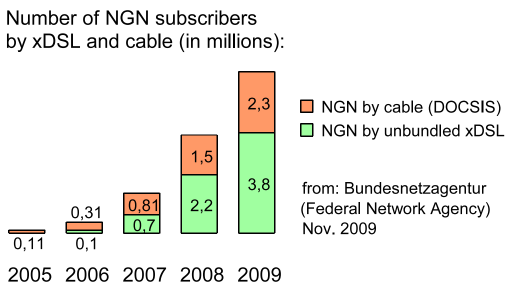

Figure 2: *NGN penetration in Germany broken down by xDSL and cable modem*

3 'Once Upon a Time' – Typical German CPE Scenarios

Figure 3 shows a scenario where a private user has subscribed for xDSL on top of the analog PSTN service. A frequency splitter –which resides in the subscriber's home– separates the xDSL signals from the analog voice signals. This situation is well known from most countries in the world.

Some additional ISDN basics:

CO

Compared to other countries, the meaning of the PSTN cloud is slightly different in Central Europe: PSTN means both, ISDN *and* analog POTS. The Central Offices (CO) became digitalized lately in the 1980s – at a time when ISDN was already invented. As a consequence, ISDN switches were installed. So the Public Network can be considered as a kind of an 'ISDN network' that also supports the traditional POTS. There is no extra gateway involved when a phone call is made from an analog line to an ISDN subscriber. The required conversion of the speech signal itself as well as of the signalling information is already done by the Line Card of the Public Switch.

DECT

Figure 4 shows the situation in a private home where ISDN is used for telephony and where the customer has upgraded the phone equipment to feature-rich digital phones. E.g. *DECT* phones *(Digital European Cordless Telephone)* are very popular. DECT base stations for ISDN have a built-in ISDN port so that it can directly be connected to the ISDN network without a terminal adapter in between.

ISDN POTS TA

Figure 5 shows a similar scenario, but the customer still uses analog telephones. The benefit of ISDN in this application is that two people can phone simultaneously. A *Terminal Adapter (TA)* is required to convert from ISDN to analog POTS and vice versa. This kind of terminal adapters is called *ISDN POTS TA*. In-house phone calls are not possible as a POTS TA does not cover the functionality of a PABX.

internal ISDN port

Figure 6 shows a common ISDN installation used by families or by SoHo users: A small PABX is installed in front of all kind of telephony equipment, such as phones, cordless phones, answering machines and fax machines. Often PABX systems include a so-called *internal ISDN port*. So the attached terminal equipment can be analog or digital. For analog terminals, the PABX acts as a gateway converting the analog signals into ISDN. Furthermore the PABX allows in-house phone calls free of charge.

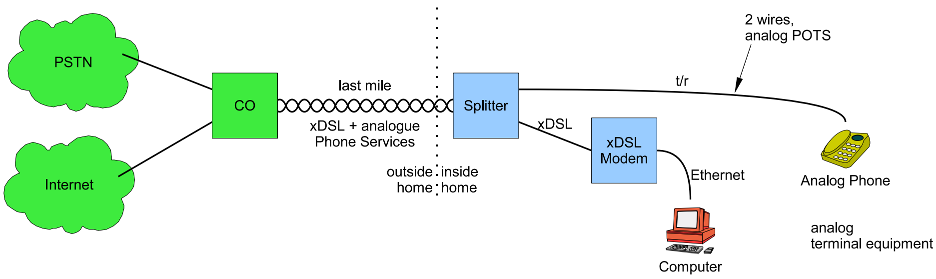

Figure 3: *Typical private home telecommunication scenario with pure analog terminal equipment*

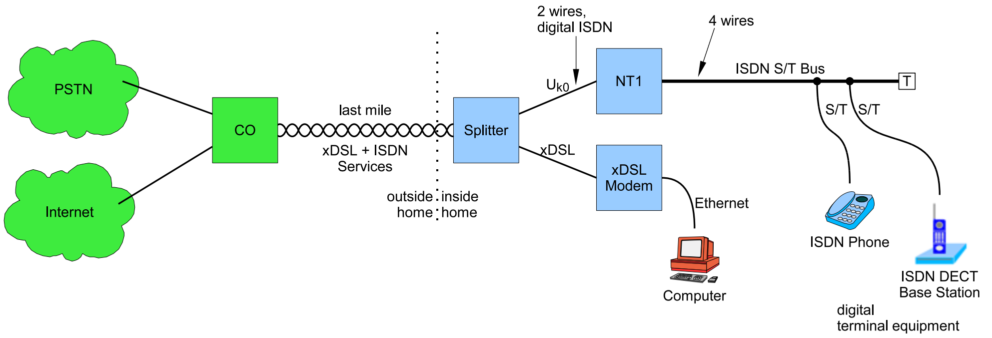

Figure 4: *Typical private home telecommunication scenario with pure digital terminal equipment*

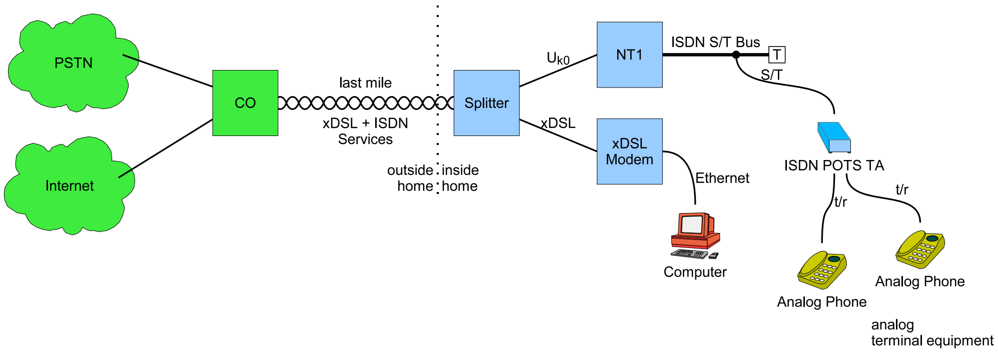

Figure 5: *Typical private home telecommunication scenario with pure analog terminal equipment*

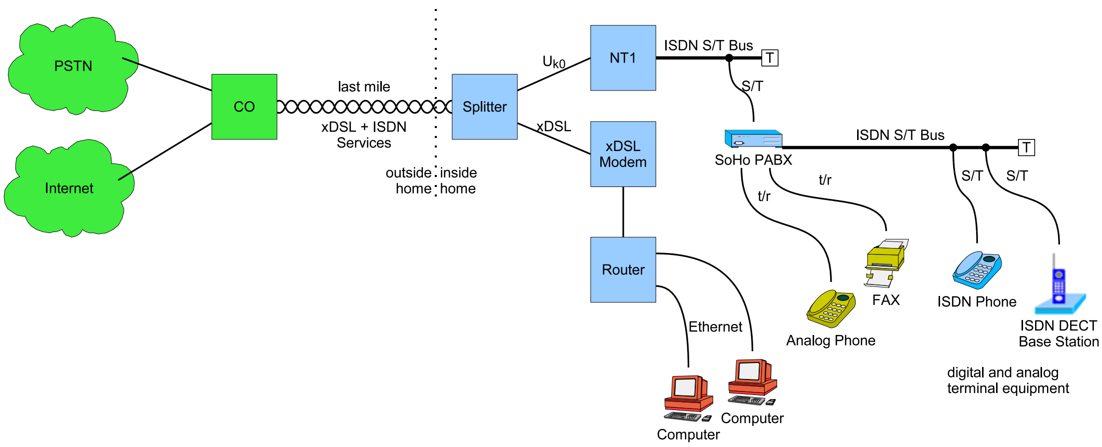

Figure 6: *Typical private home and SoHo telecommunication scenario with mixed analog and digital terminal equipment*

Once again some general ISDN basics, not related to the application described:

NT1 NTBA U-Interface U_{k0}

Figure 4 and 5 both show the *NT1* box *(Network Termination)*. The NT1 is also known as *NT* or *NTBA*. It converts the ISDN signals (on a physical level only; layer 1) from the so-called *U-Interface*, a last-mile transmission standard, into an ISDN S/T bus. ISDN U is also known as U_{k0}. It uses a full-duplex transmission method with 4B3T or 2B1Q line code over the two copper wires that constitute the last mile.

S/T S_0, S-Bus phantom power (PS1) T_0 MSN DDI

ISDN *S/T* is a 4-wired bus system with separated wire pairs for Transmit and Receive. It is also known as ISDN S_0 or ISDN *S-Bus*. Up to eight devices (e.g. phones) can be attached to the ISDN S/T bus. The NT1 provides *phantom power (PS1)* to bus-powered devices. Every terminal device is allowed to consume up to 1 W. In applications where no bus is required (e.g. connecting an ISDN PABX in SMB applications), the ISDN S/T standard can also be used for point-to-point connections. In this case it is called T_0 instead of S_0. The E-DSS1 D-channel protocol supports both standards, S_0 and T_0 which are electrically the same but differ in the protocol variants (Point-to-Multipoint resp. Point-to-Point). In S_0 applications, several phone numbers (so-called *MSNs*, *Multiple Subscriber Numbers*) are assigned by the Central Office to one ISDN subscriber line. Every terminal can be reached under its own phone number (MSN) from any place in the world. In T_0 applications, only one root phone number is assigned to the subscriber line plus a set of extension numbers (for Direct-Dial-In, DDI). For consumer and SoHo applications, only the S_0 bus architecture applies. As S_0 and T_0 are electrically identical, the international name for this interface standard is S/T. In Germany it is common to call this standard S_0 whereas the normal user does not differentiate between S_0 and T_0 – only some technicians do.

4 Today's best Solution: An Universal IAD Design for xDSL

As stated before, Telcos and ISPs prefer to have one universal IAD that can serve the needs of consumers and SoHo users – regardless of ISDN subscribers or analog PSTN subscribers.

Figures 7 to 9 show the application of such an universal IAD in the scenarios as shown in Figures 3 to 6 from page 6. The IAD contains analog FXO and FXS ports as well as two ISDN ports (marked as 'TE' and 'NT').

Universal IAD designs often include basic PABX functionality. Customers can do in-house phone calls between the NT port and the FXS ports, can transfer calls to other extensions, can assign different phone numbers to the ports an so on.

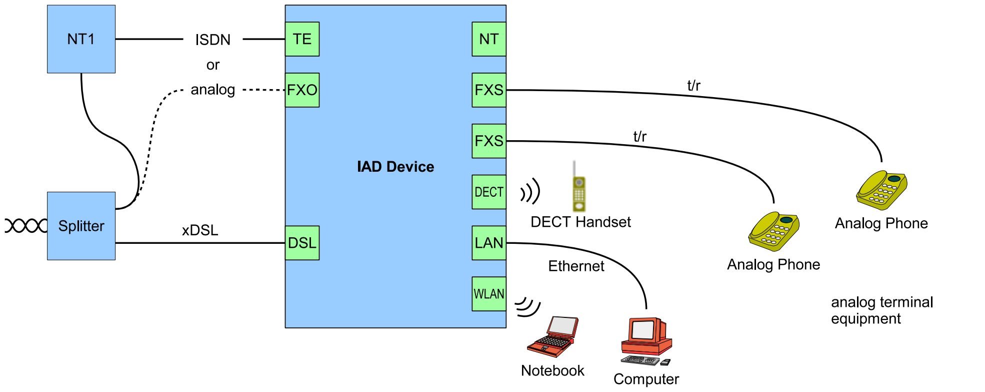

Figure 7: *IAD device with pure analog private home equipment attached*

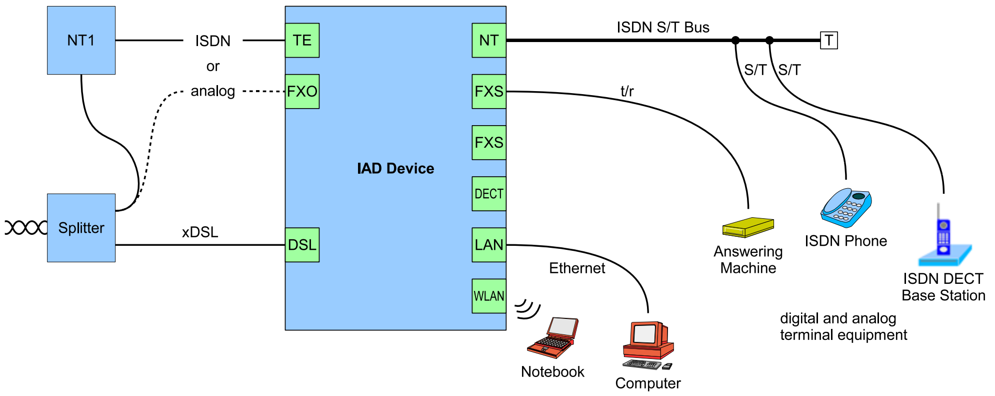

Figure 8: *IAD device with mixed analog and digital private home equipment attached*

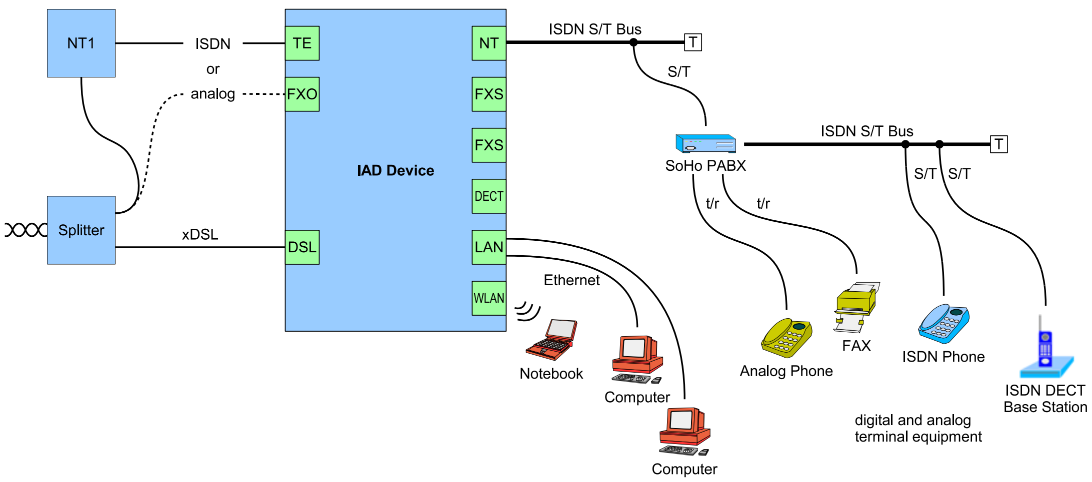

Figure 9: *IAD device with mixed analog and digital SoHo equipment attached*

Some more ISDN basics:

TE mode
NT mode

ISDN ports to the Central Office are called *TE mode ports* and internal ISDN ports are called *NT mode ports*. In ISDN terminology, TE and NT has a similar meaning like FXO and FXS in the analog world.

The ISDN S/T interface has a bus architecture, which means point-to-multipoint. Regarding its bit frame structure it obviously makes a difference if an ISDN port is used in one of several terminals on the bus *(TE mode, Terminal Equipment mode)* or if it is used as the 'master' of the ISDN bus, controlling several terminals, similar to the NT1 box. That's why this operational mode is called *NT mode (Network Termination mode)*.

Besides *different ISDN bit frame structure*, there are three more differences:

Crossed Tx and Rx wire pairs: ISDN S/T uses four wires – one wire pair for Transmit and one for Receive. The transmit wires of a TE mode ISDN transceiver are connected to the receive wires of a NT mode transceiver. As telephone cords for ISDN are straight-through cables, the wiring of the ISDN jack in the IAD must be crossed for building an ISDN port in NT mode.

Termination resistors: TE devices usually do not carry termination resistors. But usually the NT1 box is terminated. In accordance with this, an NT mode port has to be terminated (100 Ω).

ISDN power feeding: NT mode ports provide power to the ISDN bus for feeding of bus-powered telephones (38 V, usually 2 W to 4 W).

5 Different IAD Variants

In some applications there is a demand for special IAD versions. An universal IAD design can give xDSL modem manufacturers the flexibility to easily derive several IAD variants from the universal design:

WLAN as an option: Sometimes WLAN is not required, so the WLAN module or WLAN circuitry can remain unpopulated on the PCB.

DECT as an option: In recent years it has become popular to integrate DECT functionality into IADs. So current IAD designs often comprise a DECT baseband chip-set. When not required it can remain unpopulated on the PCB.

Besides WLAN and DECT there are three ISDN scenarios possible:

Full-featured IADs: 2 ISDN ports, TE and NT mode (Figure 10)
In this application, the IAD is placed in between the existing ISDN telephony equipment and the NT1 box to the Central Office. Usually the inbound calls come over the Public Network while outgoing voice traffic can either be routed to VoIP or be done with traditional fixed-line telephony (e.g. emergency calls). Some feature-rich IAD designs for business application also provide a *life-line feature* where a relay is used to connect the NT mode port to the TE port when power fails. In most CPE products such a feature is not implemented due to price pressure from the market.

life-line relay

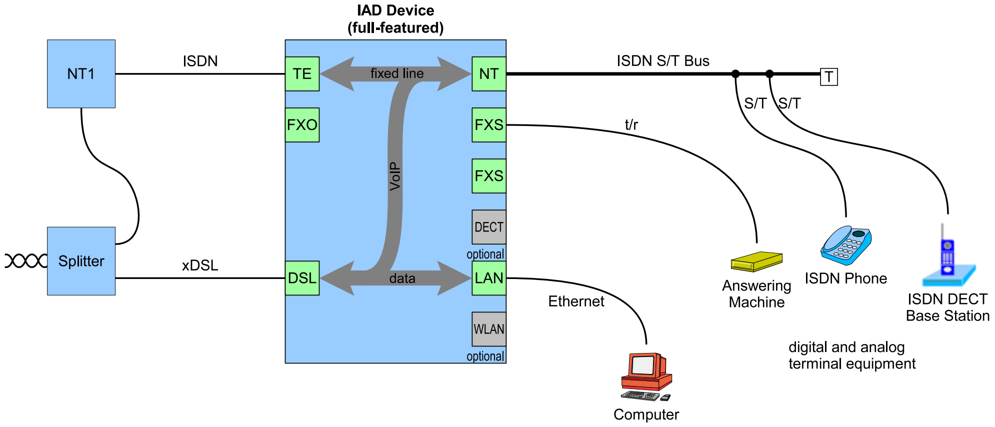

Figure 10: *ISDN pathes within a full-featured IAD device* [1]

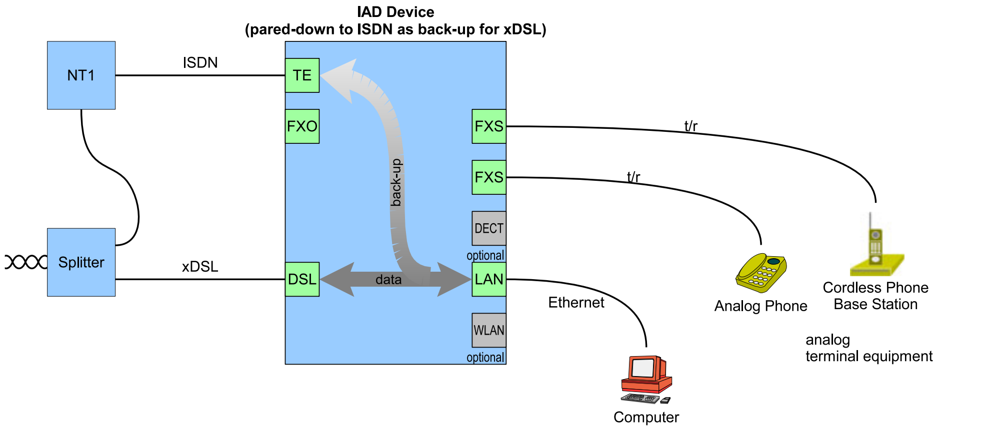

Figure 11: *ISDN pathes within an IAD device pared-down to ISDN as back-up for xDSL* [1]

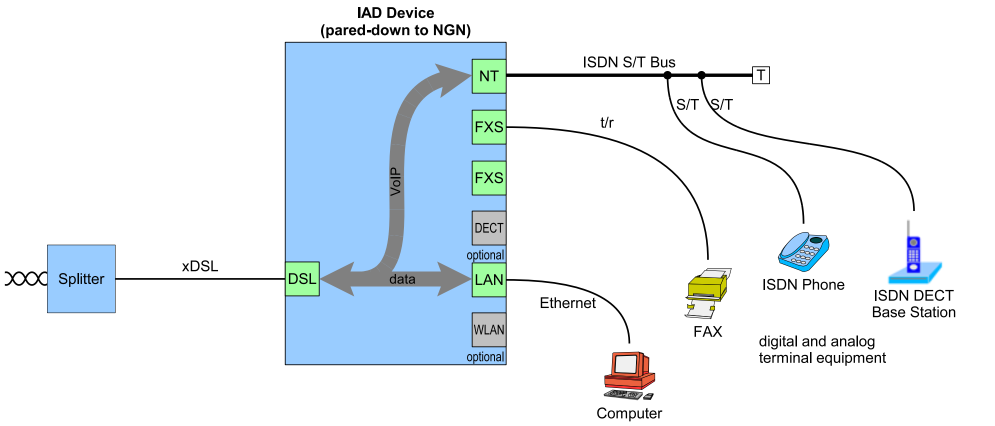

Figure 12: *ISDN pathes within an IAD device pared-down to a Next Generation Networks device* [1]

[1] Pathes to / from FXS and / or DECT are not shown in this figure. Routing from FXS (or DECT) is either to VoIP or to the ISDN TE port (if available).

ISDN as back-up for xDSL: 1 ISDN port, TE mode (Figure 11)

Some incumbent Telcos are reluctant to promote VoIP among their customers.

The ISDN network is very stable and its availability is excellent while xDSL has an availability of approximately 97 % only. So ISDN is sometimes used as a back-up for xDSL connections for Internet access. Although such an IAD does not VoIP-enable existing ISDN telephony equipment, there is a market demand for approximately 2 million IAD devices in the German market due to the xDSL / VoIP strategy of the incumbent Telcos.

Next-Generation Network devices (NGN devices): 1 ISDN port, NT mode (Figure 12)

local loop unbundling

In contrast to the incumbent operators, some regional Telcos or emerging service providers prefer to set up VoIP-based Next Generation Networks instead of traditional fixed-line telephony. By this they can save the monthly payments to the incumbent Telco to whom the subscriber line usually belongs. Instead of paying a high fee for physical access to the local loop, only the reduced fee for bitstream access is charged (unbundled DSL, unbundled local loop).

In such an IAD, no TE port is implemented. The existing ISDN equipment is solely connected to the NT mode port. All incoming and outgoing calls are transformed from and into VoIP.

XHFC series

Cologne Chip offers the perfect series of ISDN transceivers for IAD designs. The company's modern XHFC series is a chip family of 4 chips with ISDN port granularities from 1 to 4 ports. For consumer and SoHo products, the single-port device XHFC-1SU and the dual-port chip XHFC-2SU are most important while the quad-port XHFC-4SU is popular for SMB products.

XHFC-1SU and XHFC-2SU are pin-to-pin compatible. So engineers can do a common PCB layout for all three ISDN variants as described above. For the full-featured IADs, XHFC-2SU is used.

For NGN devices or IADs with ISDN as back-up, XHFC-1SU is used as a soldering option with the existing PCB layout. In this case one of the ISDN line interface circuitries remains unpopulated. In designs with ISDN as back-up (TE mode), the power supply unit for feeding the ISDN bus can also be left unpopulated on the board.

Cologne Chip is proud that the leading German Telcos rely on the company's ISDN technology: Several millions of IAD devices based on the XHFC series are succesfully used in the market.

6 Inside the IAD

Cologne Chip offers sample schematics for the ISDN part of an IAD design. The sample schematics can be obtained upon request. There is also an application note available for a very cost-efficient ISDN power supply that is fully compliant to the safety specifications for telecommunication devices.

ISDN power feeding

Usually the ISDN transceiver chip will be connected to the xDSL chip-set (or DSP) and to the CODECs (ADC / DAC) of the FXO and FXS ports in telecom-manner via the PCM / TDM inter-chip highway. All B-channels are switched from the S/T interface to the PCM bus interface of the XHFC chip. Usually XHFC allows a glue-less PCM connection to almost all telecom ICs on the market. As a part of Cologne's normal technical support, the Support team of Cologne Chip will be happy to suggest suitable PCM timings and PCM configuration settings for all ICs on the PCM bus.

CODEC PCM / TDM

The structure of ISDN network as a plesiochronous network leads to the special circumstance that the PCM bus of the IAD must become synchronous to the Central Office when attached to the Public Network. Therefore the XHFC chip has to be the PCM clock master – or has to feed a 8 kHz clock to a general clock instance of the IAD design. Otherwise slips would appear when making phone calls from any local phone to the Public Network.

synchronization

The XHFC series offers not only broad PCM configuration options but also various synchronization methods. Furthermore the chips are equipped with a microprocessor interface that can be configured to common parallel 8-bit interfaces (Motorola-style, Siemens-style) or modern

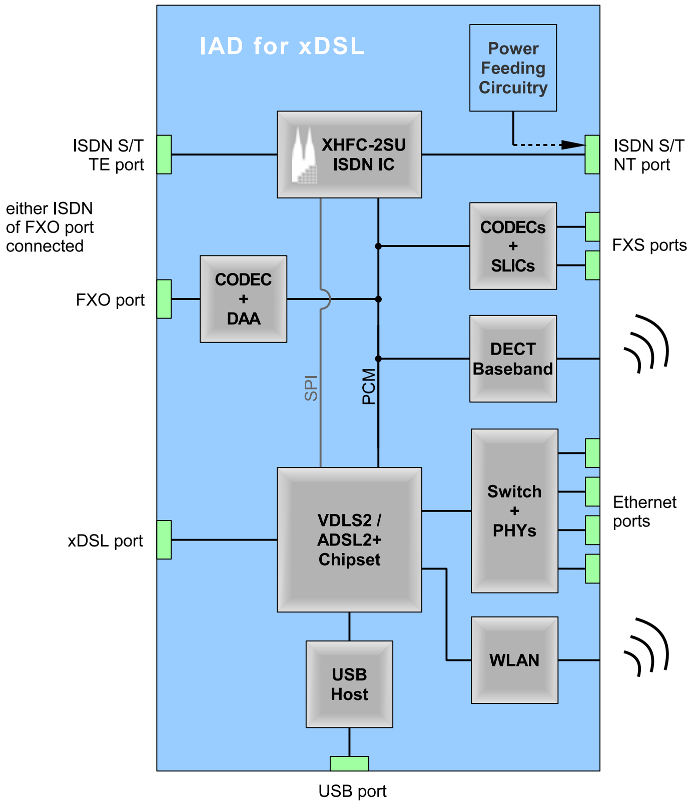

Figure 13: *Typical full-featured IAD block diagram including ISDN interfaces*

SPI serial processor interfaces (SPI). Via e.g. SPI, the ISDN chip is controlled by the host CPU and the D-channel is handled through the FIFOs of XHFC.

ISDN protocol stack Call-Control-Layer Several ISDN design houses offer the licensing of ISDN protocol stacks for the XHFC series. Besides commercial protocol stacks, also open-source Linux drivers are available under the terms of GPL. One of the main benefits to license a protocol stack from an experienced ISDN design house is the completeness of the protocol implementation and its compatibility to the Central Office. Furthermore commercial vendors offer Call-Control-Layer software on top of the ISDN protocol stack. Such piece of software is not available off the shelf in the open-source community. A list of suitable software suppliers is available upon request.

So much for the description of a traditional IAD design with built-in ISDN connectivity. But some Telcos require even higher integration and additional features: The frequency splitter and the network terminator –usually separate boxes in front of the IAD– become part of it. The following block diagram shows such an architecture. Cologne Chip provides a reference design for the transformer-less connection of an NT1 chip to the XHFC ISDN transceiver. Only a tiny resistive network is required between both ICs. This is the most cost-effective approach and –under software aspects– it does even not require any additional efforts for driver development. The NT1 chip is fully transparent for the driver software of the XHFC chip. Such an IAD can directly be connected to the 2-wire ISDN U-Interface used for the local loop.

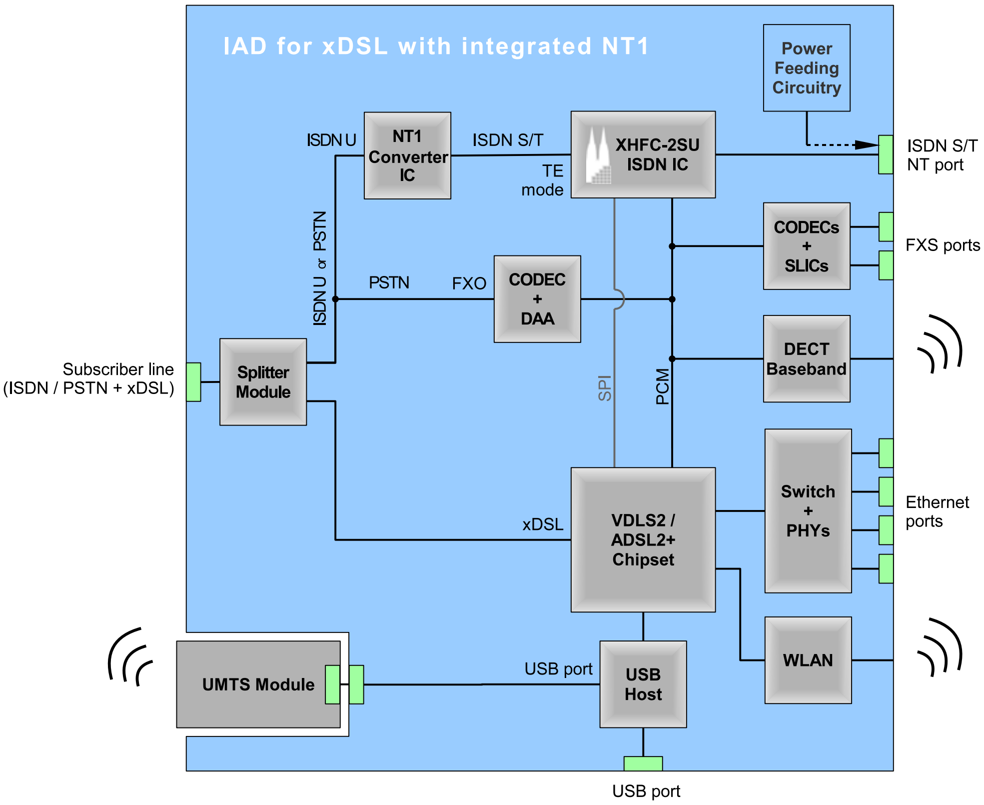

Figure 14: *Block diagram of an IAD with integrated NT1 and frequency splitter*

7 Keeping Pace with the Broadband Market

During the recent years additional features have been added to the classic IAD designs. As a result of user demand, the latest generation of IADs comes with Gigabit Ethernet ports and includes a DECT base station. But it also offers various features for Home Entertainment such as NAS support for USB-attached memories or DNLA support for Connected TV sets (i.e. streaming of video content to television sets with an integrated Ethernet port).

On the other hand, the market for broadband access technologies evolves fast, too. So IAD designs have to react as well on these changes. Since a couple of years there are IAD designs with support for 3G communications – and 4G might be the next step. By bundling IADs with UMTS modem sticks, Telcos can offer their services also to customers in rural areas who do not have access to fast xDSL lines. But even xDSL subscribers benefit from UMTS connectivity: When subscribing to an xDSL line it often takes several weeks –due to administrational issues– until the line becomes activated. UMTS is used as a backup for xDSL during this period. Another way of 3G connectivity could be the integration of UMTS femto-cells into IADs. Providing a G3 base-station for in-house usage, such IADs could relieve the public G3 networks from a large portion of Internet and voice traffic and route this data via xDSL to the Telco. At present this type of IAD is only known in trial installations and not yet deployed to the mass market.

3G, 4G
UMTS
femto-cell

In the race for bandwidth, xDSL technologies nowadays compete with cable modem technologies (DOCSIS 2.0 and DOCSIS 3.0). As the market for Internet access and telephony via cable modem is just picking up in Germany (see Figure 2 on page 5), the designs of embedded Multimedia Terminal Adapters (e-MTAs), a combination of cable modems and telephone adapters, are likely to develop like IADs: More and more features are being added. In 2010

DOCSIS
e-MTA

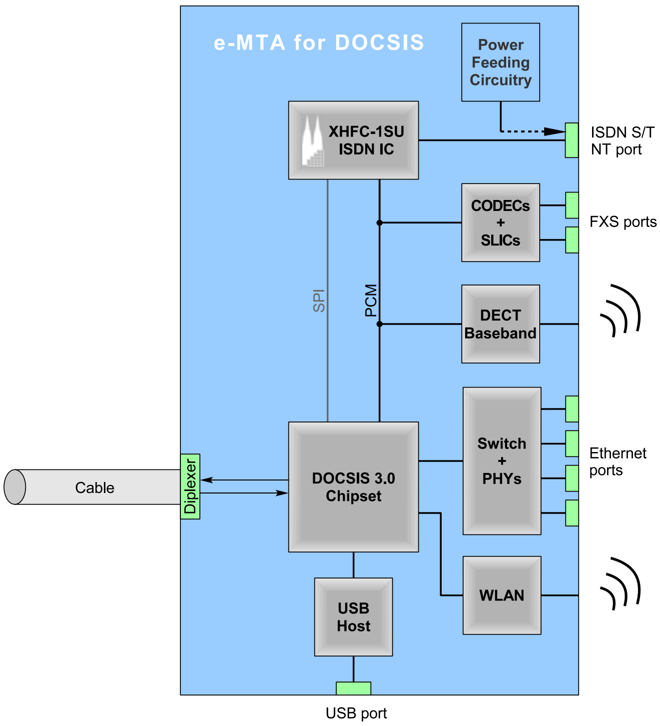

Figure 15: *Block diagram of an e-MTA (DOCSIS cable modem)*

the first e-MTA devices with integrated ISDN have been introduced to the market. As DOCSIS 3.0 offers significantly higher data rates than VDSL2, there will be a high momentum for this access technology.

Fiber Optics

The current decade will be the dawn of a new era with fiber optics as predominant access technology. At present there are only some trial installations of FttH in green-field scenarios. But yet the first IADs for fiber-based NGNs are already available with integrated ISDN ports.

In the mid-term there will be a substantial market for feature-rich e-MTAs and FttH-CPEs. It is very likely that these devices have to offer the same enormous set of features like today's IADs. The following figures show the various variants of CPEs. In xDSL technology the frequency splitter might be removed as a next step.

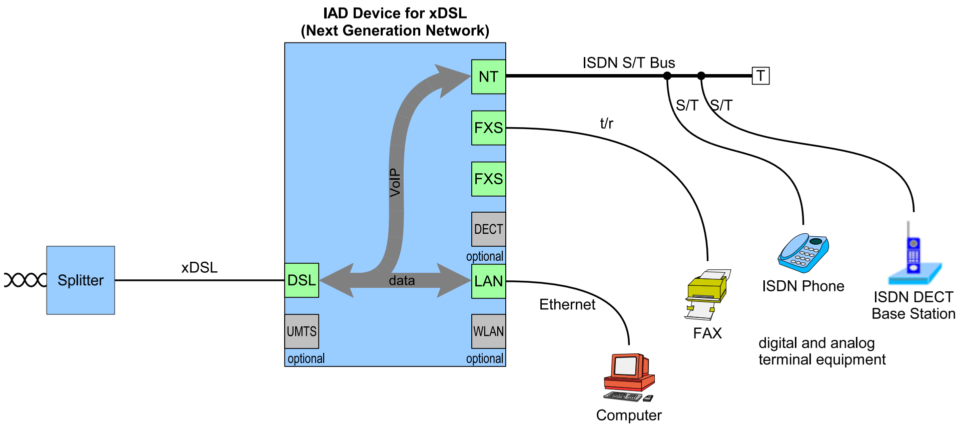

Figure 16: *IAD for NGN applications based on xDSL technology*

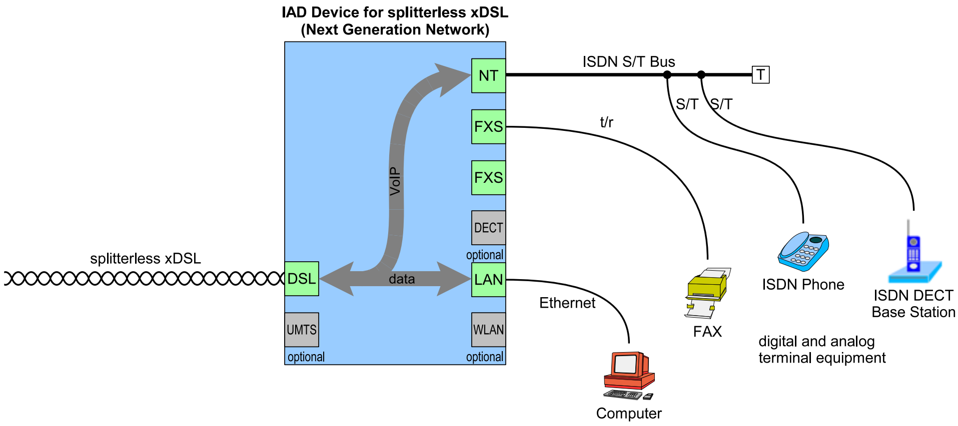

Figure 17: *IAD for NGN applications based on xDSL technology without frequency splitter*

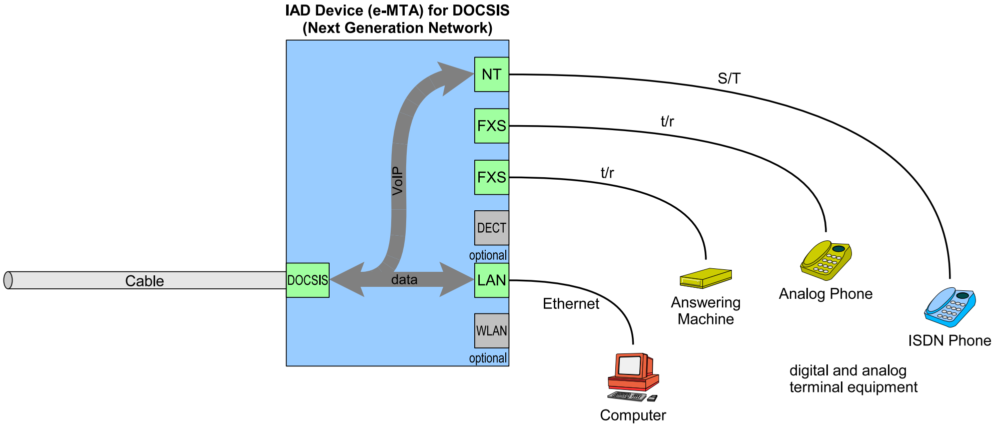

Figure 18: *e-MTA (cable modem) based on DOCSIS technology*

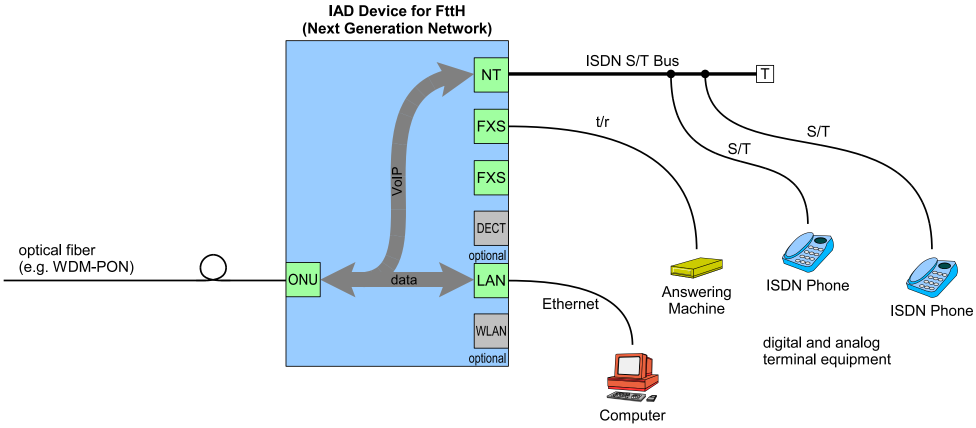

Figure 19: *Optical Network Unit (ONU) for FttH networks*

As a second trend there will be a large demand for entry-level CPEs. Telcos will give such devices to their existing customer base of voice-only subscribers. This is necessary for a smooth transition from a from a circuit-switched voice network to a packet-switched next generation network.

In any case –whether it is xDSL, cable or fiber optics, whether it is for Converged Networks or for NGNs and whether it is for high-end CPEs or for entry-level products– ISDN connectivity is a mandatory feature for IADs. It is required in all countries with a high ISDN penetration.

The team of Cologne Chip is looking forward to assist you in creating the CPE products for tomorrow's markets.

Cologne Chip AG

White Paper