HFC Access Network Technology Evolution

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1) The scale of cable TV two-way network subscribers in China

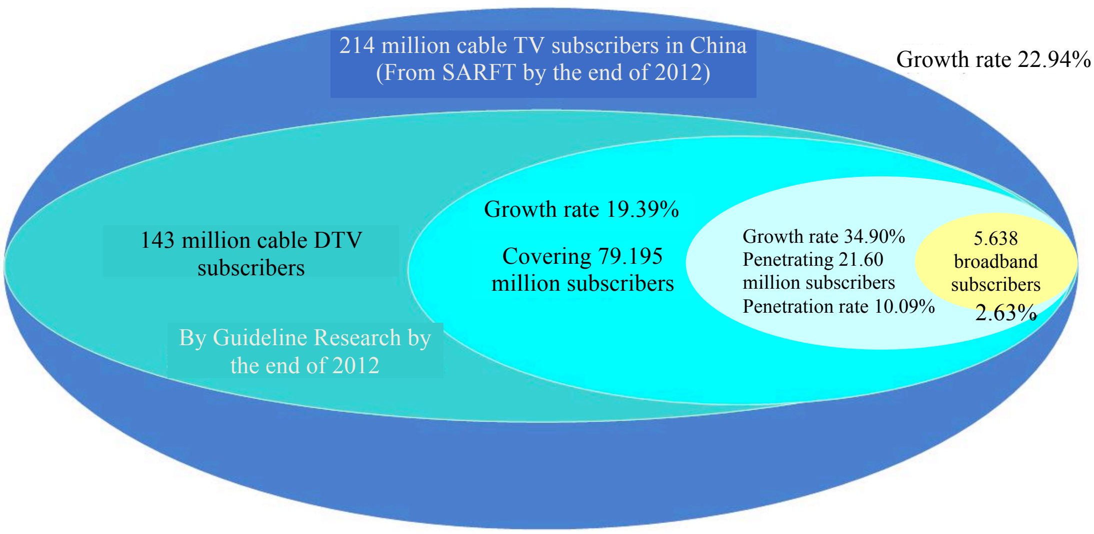

Figure 1 Two-way Transformation Coverage and Penetration in Q3, 2012 by Guideline Research

As shown in Figure 1, there is 40% coverage but only 10% penetration for the cable TV network in China. On one hand, it indicates low level of overall development; on the other hand, it indicates great potential in the market. In recent years, two-way coverage is growing steadily, and its penetration rate and business are growing rapidly.

2) The market share of cable TV two-way network transformation technical solutions in China

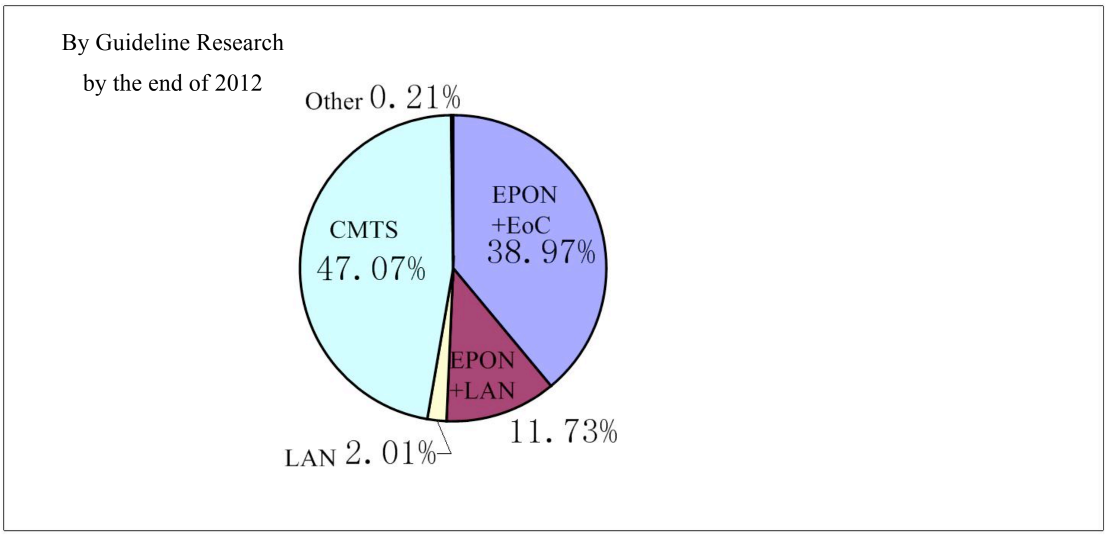

Figure 2. The market share of two-way transformation technologies in Q2, 2012 by Guideline Research

As shown in Figure 2, CMTS technology covers most subscribers but the growth tends to slow down. In previous two years, since CMTS mostly covers developed areas with fast business growth in a wide range and it also has mature set-on-top solution, therefore the penetration rate grows rapidly. In particular, BGCTV alone has increased 2.80 million set-top-boxes with built-in CM, which contributes 50% of CM penetration rate. With the gradual completion of two-way transformation in these areas, the growth of DOCSIS slowed down in 2012.

EPON+EoC and EPON+LAN solutions have grown fastly in recent years, and subscriber penetration has stepped into a fast growth period. However, since they lack of mature and economical set-top-box solution, they haven't reached the CM explosive growth in the precious two years.

3) Pure LAN coverage subscribers stop growing.

As shown in Figure 3, several EoC technical solutions coexist, and HomePlug AV is most widely used, which accounts for more than half of the market share. The network bidding invitations in most provinces include HomePlug AV.

There is a new development trend in recent two years: High and low frequency hybrid adapts to different scenarios. With further development of optical fiber, FTTB accounts for more and more proportion, which can reach 30% or so at present or even above 90% for a few rapidly developed areas. In this scenario, high frequency EoC is the ideal solution. However, FTTB accounts for a low percentage in most areas, and low frequency solution is more suitable for areas with high transmission loss. Taking Chengdu for example, MoCA (C.link) solution is chosen for FTTB, and HomePlug AV is chosen for the suburb. High and low frequency hybrid even benefits FTTB: Firstly, it can effectively use the spectrum resources and increase bandwidth supply; secondly, it can distinguish different services. Taking Henan for example, set-top-box with under frequency WiFi is used to reduce the cost, and HomePlug AV is used for PC networking; two services are separated to ensure the set-top-box free of attacks.

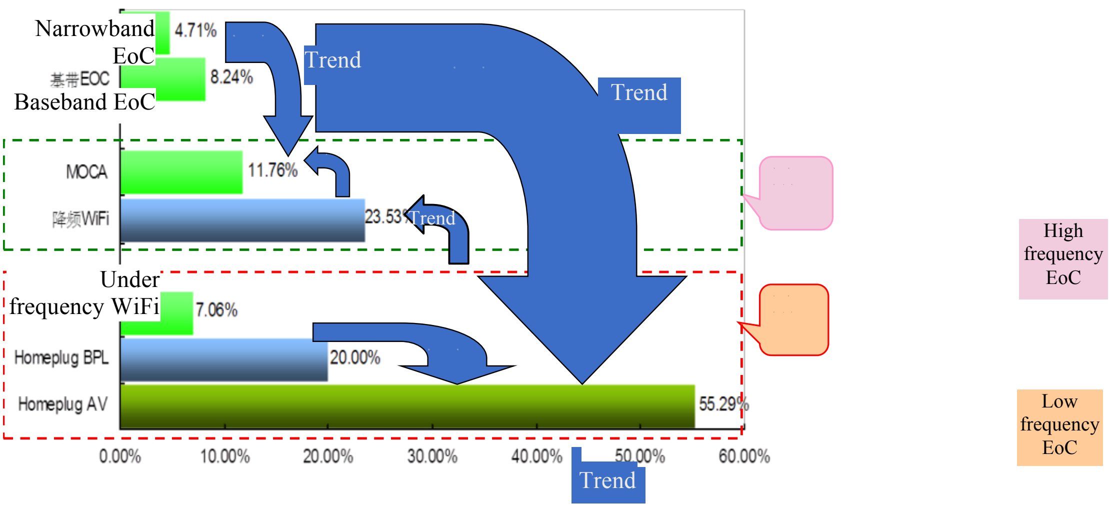

Figure 3 The general view of EPON+EoC concrete proposal selection in main provinces and cities in Q2, 2012 by Guideline Research

4) EoC Technology Development

In recent two years, more than ten technologies have converged into three standards (HiNoC, C-DOCSIS, HomePlug AV) recommended by the SARFT in China's EoC market: HPNA and HomePlug BPL have already withdrawn from the market and ceased to develop; Under frequency WiFi currently starts to shrink from a former large market share, since it lacks support from the chip manufacturers and equipment manufacturers gradually quit; Baseband and narrowband have already completed their mission.

MoCA is the only technology which continues to grow without recommendation from the SARFT: New subscribers in the previous year almost equal to the total number of the past few years. There 200 thousand subscribers in Chengdu alone.

In general, the technologies under development mainly include HiNoC, C-DOCSIS, C-HomePlug AV and MoCA.

We present several technologies under development in the following section.

1. HiNoC

As shown in Figure 1, HiNoC has been developed for 8 years since its initial conception in 2005. ITU-T initiated J.HiNoC research in May, 2012; HiNoC1.0 was approved by the SARFT on August 3, 2012, and HiNoC1.0 was released on August 16.

HiNoC is designed for coaxial access and has proprietary intellectual property rights: it adopts distributed channel equalization and integrates signaling frame and probe frame, which eliminates the need for independent frame and increases spectrum efficiency; it introduces frequency diversity "OFDMA" to quickly send the request and overcome the large delay of TDD request etc.; it has its own patents and innovations in PHY and MAC layers.

HiNoC2.0 has already been studied, and it has already determined 128MHz single channel spectral bandwidth, TDD duplex mode, TDMA/OFDMA multi-access mode, OFDM modulation, QPSK-4096QAM adaption, BCH/LDPC encoding, and 1Gbps highest throughput.

1.x industrialization is the weak link but has made progress: Commercial chips will be launched after Chinese Spring Festival; 2.0 prototypes will be exhibited at the CCBN.

EPoC presents both challenge and opportunity to HiNoC - competition, exchange and convergence.

EPoC and HiNoC are two irrelevant technologies for now, which are studied by respective standardization organizations. Since their spectral range is also overlapped, there will definately be competitions. But what they have in common is their focus on coaxial PHY, OFDM/OFDMA modulation and LDPC encoding; EPoC uses EPON MAC, and HiNoC also adopts the advantages of EPON MAC. Many members of HiNoC2.0 research group are also members of EPoC standardization group, and join IEEE EPoC conferences (including members of non-EPoC working group) - the competition encourages the HiNoC research.

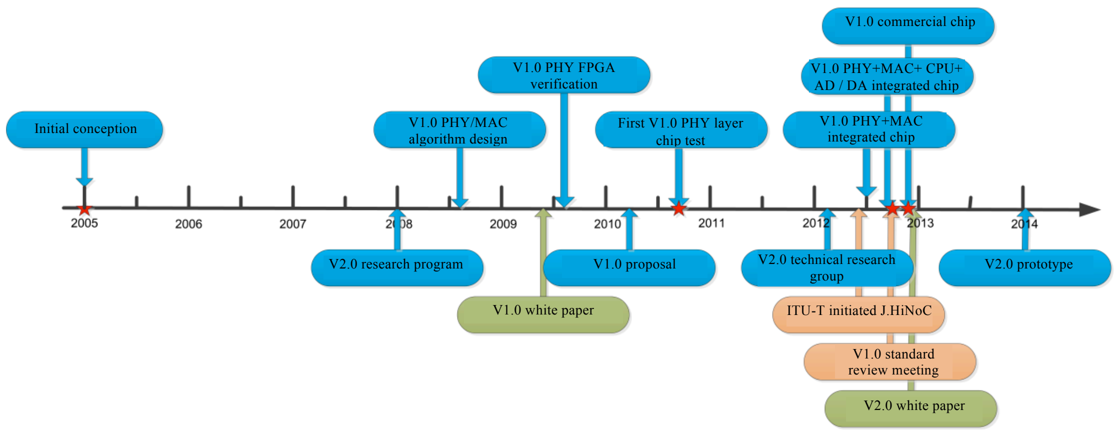

Figure 1 HiNoC development history (provided by Cui Jingfei from Cable TV Technology Institute of Academy of Broadcasting Science)

Therefore, HiNoC can sufficiently absorb international advanced technologies and learn from others' strong points to offset its weakness; meanwhile, it outputs China's independent innovation, influences and dominates the international standard. It has already done so. We hope that both technologies can converge and integrate, but firstly they should unify the terminals.

In this respect, we should learn from CableLabs, and make good use of every available resource. For DOCSIS3.1 and previous AMP project, they sent letters to manufacturers with strength and requested them to provide schemes; For EPoC, they try to dominate and initiate to study architecture and equipment specifications which is studied by IEEE and must be solved during the system implementation; it takes advantage of its leading role to unify PHY layer of EPoC and DOCSIS3.1. PON's MAC has much resemblance with that of DOCSIS, which makes it possible to manufacture an integrated central office chip.

2. C-DOCSIS

In April of 2010, Broadcom proposed DOCSIS EoC conception, which coincided with Chinese cable operators' thoughts to marginalize CMTS and reduce unit bandwidth cost. Afterwards, Chinese cable operators lead to transform DOCSIS EoC into C-DOCSIS, one of three NGB access network standards, which was approved by experts on August 6, 2012, and released on August 17.

The current basic architecture (centralization) is to separate second and third layers and marginalize first and second layers, which is suitable for EoC applications. Router convergence is accomplished by EPON OLT instead of CMTS Core. It is difficult and problematic to maintain the former DOCSIS architecture: the main problem is that it still cannot support end-to-end QoS and dynamic QoS. Therefore, although many operators who adopted DOCSIS architecture carried out tests, they are reluctant to deploy; instead, Wasu who did not adopt DOCSIS architecture started commercial trial.

Distributed architecture only puts RF modem in the margin (this publication has published my proposal on this architecture), which can keep the former architecture, theoretically further cut the prices, maintain and manage more easily, and better meet the requirements of the operators who adopted DOCSIS architecture. However, domestic manufacturers did not make R&D investment on the architecture, and only Cisco promoted the R&D.

The biggest contribution of C-DOCSIS is that it broke up the monopoly of foreign equipment suppliers, and many domestic manufacturers reduced the unit bandwidth cost by 1-2 orders of magnitude.

C-DOCSIS has gone through several tests, and completed lab functional verification, performance test and existing network test.

According to the tests in Shenzhen Topway, the results basically live up to the expectation. Table 1 shows the Shenzhen test results. They are fully compatible with 2.0CM, there are some problems for some set-top-boxes, and 1:2 packet throughput is lower. It is a pity that chips are monopolized by Broadcom and there are no ASIC chips currently.

1:96 DOCSIS2.0 Test

Frame size (Bytes)	Throug (Mbps)		Delay (μs)		Packet (%)	
	Downstream 256QAM 16CHB	Upstream 64QAM 4CHB	Downstream	Upstream 64 QAM	Downstream	Upstream 64 QAM
64	770	104.375	599.93	15649.19	0	0
128	832.54	95.28	647.48	19264.84	0	0
256	804.22	97.66	749.12	22087.93	0	0
512	812.81	98.84	914.73	20530.51	0	0
1024	810.59	97.50	1271.78	19931.04	0	0
1280	808.05	100.00	1453.73	22090.9	0	0
1518	806.41	91.64	1621.22	21216.87	0	0

Reported by Ouyang Shijie from Shenzhen Topway Video Communication Co., Ltd.

Table 1 Shenzhen Topway C-DOCSIS existing network test data

3.C-HomePlugAV

The greatest advantage of HomePlugAV is a robust PHY, which can still keep connected in the severe environment, and this is the main reason that operators choose HomePlugAV. Poor delays and jitters, reduced short frame performance and reduced multi-user access performance are also weak links of AV. C-HomePlug AV has made improvements in these respects. The services which require low delay and high short frame performance mainly include voice communication and video games. Voice service is unlikely to see large-scale applications recently, and video game delay is hindered by the gateway instead of network access; end-to-end delay can be ensured by setting VPN and VLAN to high priority. Video service is sensitive to jitters, and we use buffer to smooth jitters on the IP network. Therefore, C-HomePlug AV can basically carry the broadcasting and TV services at the current stage, and the operator's practice also proves it. It is definitely not the case that AV cannot be used for access.

It is expected that it can pass through the review and release the standards before CCBN.

Currently, the main chip supplier Qualcomm regarded C-HomePlug AV as the transition to EPoC, with the primary focus on implementing TDMA, improving multi-user access, enhancing delay, packet, multi-cast and DBA performance as well as solving TDMA and AR6400 compatibility problems by means of software. It will also launch inexpensive set-top-box solution chip and SoC chip to meet the large-scale application at current stage.

M-Star currently focuses on solving time delay and backward compatibility problems, and actively joins the C-HomePlug AV standardization group. It will further launch 1Gbps chips which are compatible with HomePlug AV2 PHY.

It is expected that chip standards from various manufacturers can be unified and interoperable, which is not achieved yet.

4. MoCA

As mentioned above, MoCA grew rapidly in 2012, which is basically the sum of previous years. Main drivers: WiFi gradually withdraws, HiNoC is not industrialized yet, C.Link is developed in China, and high and low frequency hybrid made success, which both support access and home networking. The primary advantage of C.link is to optimize the video application, with excellent delay and jitter performance, which is even better than FDD DOCSIS. This is also the main reason that wins the operators' recognition. Currently, C.link can implement three-channel bonding, which reaches 500Mbps throughput. The imperfection is low spectrum efficiency. It is not a big problem in the home network, because the entire frequency spectrum is provided for one user; But it is an apparent defect for access network, because the spectrum is shared by users in the access range. However, it is sufficient for 50 users to share 500Mbps. In addition, like most EoCs, the short frame performance is inferior to the long frame performance.

Table 2 is the development path of C.link. We can see that C.link 1.1+ and 2.0 have increased the spectrum efficiency.

Version	NC throughput (Mbps)	CPE throughput (Mbps)	Occupied spectrum (MHz)	Process (nm)	Time (year)
EN32xx (c.LINK 1.0)	130	130	50	65	Now
EN35xx (c.LINK 1.1)	175	175	50	65	Now
EN368x (c.LINK 1.1+)	800	200	4×50	40	2013
EN388x (c.LINK 2.0)	1600	400	4×100	28	2014

Table 2 The development path of C.link

5. ECAN-DECO

ECAN and DECO are EPON MAC-based technologies. The main advantage of ECAN is carrier-class architecture with powerful central office functions and sophisticated management and QoS scheduling mechanism, which adapts both point-to-point and point-to-multipoint architectures; the terminal is simple, inexpensive and easy to maintain and manage; Multi-terminal and long and short frame performance are basically the same. However, because of various reasons, PHY with VSB modem has poor anti-interference performance and narrow link loss tolerance range, which only suitable for FTTU scenarios. The main advantage of DECO is SoC, and it has adopted advanced OFDM modulation and LDPC encoding, therefore it has excellent performance and lower price. But the terminal and central office adopt the same architecture, and system management, control and QoS scheduling are insufficient. Now some manufacturers have combined both, and use ECAN architecture and DECO modulation and encoding to form an ideal solution; moreover, the solution is consistent with the EPoC development trend. Although ECAN-DECO has many advantages above, it is born at the wrong time: since it went to market after SARFT recommended three standards, it lacks policy support and powerful industrial chain. Today's competition is the competition of the industrial chain instead of pure technical competition. A superior technology cannot succeed without the support of the industrial chain. Studying technologies is different from formulating standards, since researches always pursue the most advanced and perfect solution; but standards must represent the majority interest, and they are always the compromise between the general technical level and various parties' interest. Therefore, the only hope for ECAN-DECO's success is to approach EPoC/HiNoC. Now most manufacturers in this camp are very clear about it. If a few people do exactly the opposite, it will be opposite to what they wished.

5) The future technological development trend

The basic trend of the network development is large broadband, and coaxial access network can reach 10Gbps. To achieve the goal, the technological development trend is multi-channel binding and high modulation rate - 4096QAM and above; the mainstream modulation technology adopts OFDM/OFDMA; the corresponding error correction of coding approaches to Shannon limit coding - LDPC.

Another development trend is wire and wireless coexisting as well as many technologies sharing the spectrum. To achieve this goal, the technological development trend is software radio and cognitive radio. FBC (Full-Band Capture) - it means the specific applications which have been implemented at present.

The development trend of broadcasting & TV network is multi-service support, from simple broadcasting for public needs to IP, to meet the differentiated needs. In large coverage, there will be common needs - 80% needs are satisfied by 20% contents, therefore it is most cost effective and efficient to use broadcasting to provide 20% contents; With the reduction of wired network service nodes, the individual needs are becoming more and more obvious. The cost advantage of broadcasting is not obvious and frequency spectrum benefit will obviously decrease; IP trend of unified switch, unified transmission and unified terminal is becoming obvious. Therefore, the broadcasting applications will gradually decrease, IP will replace the broadcasting, and this is an irreversible trend.

There are two trends which cannot be ignored - end-to-end Ethernet and the transition from IPV4 to IPV6. The Ethernet has evolved from LAN to MAN, and continued to extend. IPV4 addresses are depleted, and transitioning into IPV6 is the only way out. IPV6 deployment has far-reaching influence on the network security and management such as management, control, network real-name system and source-tracing.

At last, high centralization and high distribution are two developing trends: With the rapid increase of rapid computing power, storage capacity and transmission bandwidth, scheduling, controlling and other service platforms are moving to the cloud; the application selection and processing are distributed among the terminals, there will fewer and fewer middle processes and levels, and there will only transparent channels left. First of all, the access network will be highly integrated: The integration level will increase by 1-2 orders of magnitudes, and the power consumption will decrease by 1-2 orders of magnitudes, which will eventually diminish.

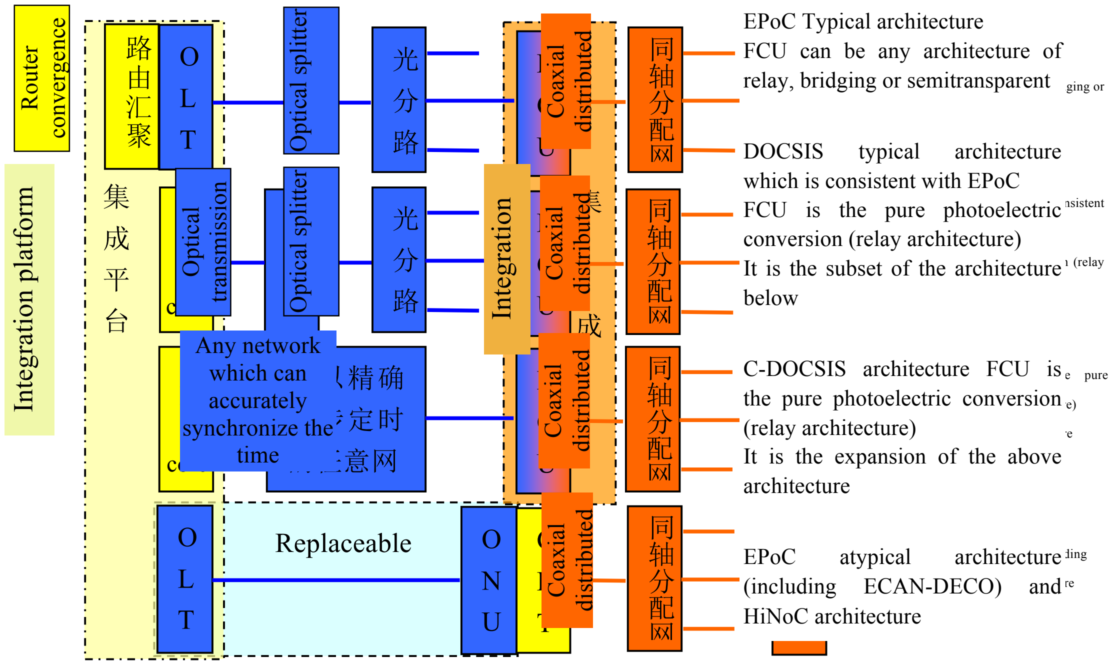

Figure 2 Next generation technical architecture

Next generation access network will or should embody these development trends. EPoC, DOCSIS3.1 and HiNoC2.0 have more or less adopted the above technologies.

Convergence is a trend in the world today, which also reflects the development trend of high centralization. We hope HiNoC, C-DOCSIS, C-HomePlug AV, ECAN-DECO and EPoC will choose the same road - various EoC technologies (C-DOCSIS is also one of EoCs in terms of architecture) will converge and unify.

As I said above, C-HomePlug AV is a transition technology of this generation, and the future evolution trend is EPoC, which is explicit. As for C-DOCSIS, as mentioned earlier, DOCSIS3.1 PHY has already unified with EPoC, and C-DOCSIS will inevitably unify. If HiNoC can unify three powers into one power, and unify the PHY, it is favorable for the chip convergence and terminal convergence.

DOCSIS is very similar to PON from architecture to control and scheduling; It can be deemed that PON referenced and simplified DOCSIS. As shown in Figure 2, if DOCSIS architecture completely unifies with PON, and DOCSIS MAC contains PON MAC, then it can achieve unified terminal, unified central office and unified FCU.

The divided technologies which share the market are less favorable to the operators and the industry than one unified technology.

From the current situation, DOCSIS3.1 has a complete industrial chain and its vitality is beyond question; EPoC has the complete industrial chain strength, and is supported by international standards, which make it possible to win out; If C-DOCSIS transforms into DOCSIS3.1, it will have a secured future, or else it will have an uncertain future; HiNoC2.0 is supported by the state policy and has sufficient research strength - research institute, universities and colleges, several chip manufacturers joined the research group, which is much better than 1.0 version. However, the industrial chain is still incomplete - few operators participate, equipment suppliers hardly get involved, and the future is obscure. If HiNoC can complete the industrial chain as soon as possible and pick up the speed, it should be hopeful: Compared with EPoC, HiNoC has fewer restrictions and more flexibility, and it is easy to choose the optimal solution. Since EPoC is limited by IEEE and cannot exceed the PHY restrictions, many problems are difficult to solve.

6) The life cycle of coax

It is often mentioned that how long is the life cycle of coax during the FTTH period? My prediction is optimistic.

First of all, Chinese cable operators do not have FTTH advantages: Telecom PON has much lower centralized procurement cost than cable operators; FTTH has a low initial ROI, and ODN construction investment is mostly sunk capital. If the telecom transforms into thin coverage now, the engineering cost will be high. Most cable operators cannot afford such large-scale investment due to lack of capital accumulation. Considering the competition, the consumers may not choose cable operators in terms of FTTH, and it is likely that the investment cannot be recovered.

Secondly, EPoC and DOCSIS3.1 can reach 10G PON, which means coaxial distribution network bandwidth is comparable with optical fiber.

The life cycle of the coax depends on whether it has sufficient spectrum resources, which can continue to meet the needs of business development on the bandwidth. Spectrum resources depend on transmission distance and spectrum application policy. Coaxial cables do not have special allocated spectrum resources, and they can be used as long as they do not interfere with wireless applications and the transmission link can reach a certain signal to noise ratio. Taking HFC network for example, in the context of FTTB, 1GHz link loss of coaxial cable distribution network is 40dB or so for 50 households, non-interference SNR can easily exceed 50dB and the spectrum efficiency can reach 12bit/s/Hz/. Total bandwidth can reach 12Gbps. In view of interferences, assuming 70% availability ratio, 8.4Gbps is divided by 50 users, and static bandwidth can reach 168Mbps/household. If 1:5 converges, the dynamic available bandwidth can reach 840Mbps. If spectrum expands to 3GHz, the link loss can be less than 80dB. Based on a conservative estimate, 2GHz spectrum bandwidth between 1GHz-3GHz equals to that below 1GHz, and the average dynamic bandwidth per household can reach 1.68Gbps. Furthermore, 3GHz link loss of FTTU can be less than 40dB, and 3GHz spectrum bandwidth can reach 3×8.4G=25.2Gbps.

The spectrum application policies will have a significant impact on the future coaxial available spectrum and bandwidth frequency. There are usually 4-20 TV broadcasting channels in each region, and there are no wireless applications, therefore the coaxial resources are not constrained. Once the spectrum resources are developed and utilized, the coaxial available resources and spectrum efficiency are inevitably affected.

The bandwidth needs depend on the business development and codec technological development. Currently, the service which consumes most bandwidth is video: One H.264 HD broadcasting video stream needs a bandwidth of over 12Mbps, and Ultra HD TV with same encoding needs 160Mbps. With the improvement of the encoding technology, the bitrate can be reduced; therefore the coaxial can sufficiently meet the bandwidth needs of Ultra HD TV development.

From the perspective of engineering, the life cycle of coaxial cable is also related to the service life of coaxial cable. The service life of optical cable can reach 30 years, while the service life of normal cables can only reach 7-10 years. If the gap cannot be solved, the maintenance cost is higher than optical fiber and the overall cost price ratio is inferior to optical fiber, although the coaxial distribution network bandwidth is comparable to optical fiber, and the construction cost has advantages over ODN. The major factor that influences the normal cable service life is oxidation of shielding net eroded by humidity at the joints. If the manufacturers can manufacture sealed joints or solve the sealing problems by using fabrication process, the expected service life can extend for more than 20 years.

The process of optical access for replacing copper access may last for 20-30 years, or even longer. It is expected to last until 2040 in the United States, while China's coaxial application conditions are better than the United States because of dense habitation in China; the competitive environment is inferior to the United States, and the coax should have longer life cycle.

It is important for the cable operators to make the most of and exploit the values of coaxial resources, and strive for competitive advantages. For this reason, fundamental research will be strengthened: Channels (basic features, parameters, wired and wireless coexistence), cable (hardly any progress in the past 10 years), branch splitter (spread spectrum), connector (loss, matching, reliability, tightness, life, joining technology). No matter how the technology is developed, fundamental network construction will always come first!