致 IEEE EPoC SG 明尼苏达会议

尊敬的主席先生、尊敬的各位专家、各位朋友：大家好！

值此大会召开之时，谨致亲切问候和热烈祝贺！

EPoC 源于中国的 EPON+EoC，是中国有线运营商在接入网建设、改造过程中创造的模式，目前已经成为双向化改造的主流方案之一。EPON+EoC 架构由于简单、价廉，不仅在中国得到普遍推广，还引起了国际同行的关注。各国 MSO 受竞争压力，都在探索新一代 HFC 技术，寻求更低成本的、IP 化的、统一管理、统一运营的全业务解决方案。

ＥoC 缺乏统一标准，不是端到端的解决方案，因此在中国实际应用当中碰到许多问题。EPoC 发展了 EPON+EoC，一经提出就引起各国有线运营商广泛关注和赞同——不是因为 EPON MAC 多么优秀，也不是因为 EPON MAC 多么适应同轴环境，而是因为端到端——端到端的管理、控制、调度，端到端的 QoS；还因为简单、通用、符合端到端的 IP/以太网发展方向。这也是中国有线运营商支持 EPoC 的根本原因。同时，中国有线运营商把 EPoC 当作与 FTTH 竞争的一种重要手段，也许是唯一可能的手段——中国有线运营商在 FTTH 上没有多少机会，也没有竞争优势，因此对 EPoC 寄予极大的希望。

我们欣喜地看到，EPoC 标准的研究工作在大家的共同努力下正在稳步前进，特别是会议前期关于 5 项准则的讨论，表达了所有成员对 EPoC 标准的期盼。我们虽因种种原因没有直接参加会议和讨论，却始终关注 EPoC 研究的进展。以下几点是我门的主要观点：

1、关于 FDD 和 TDD

近期关于 FDD 和 TDD 的讨论尤其使我们感到振奋：同时支持 FDD 和 TDD 是中国有线运营商一直的诉求，现在得到了越来越多的赞同。我们希望能对同时支持 FDD 和 TDD 有进一步的、实质性的研究和进展。这是一件十分有学术价值又有现实意义的事情。

FDD 和 TDD 曾经是前期讨论的热点和焦点，是第一个引起争论的议题。FDD 频分对应波分，是最简单、直接的转换；比较容易处理相邻信道干扰（同向电平相当）；双向放大容易实现，可以适应多级放大网络；时延较低。但在 FDD 条件下实现灵活配置频谱有不少难点：第一，需要将双向频谱之和全频段解调（与 TDD 相同），第二，需具备可变滤波或可随时更换滤波器的条件，复杂度、难度、成本大大增加。如果要保证分割点不改变，必须一次性按照最大带宽要求规划好频谱——这几乎不可能——双向对称 10GEPON，需要物理频谱 2×1GHz(4096QAM)或 2×1.2GHz(1024QAM)，全世界那么大，很难统一规划，很难根据频谱

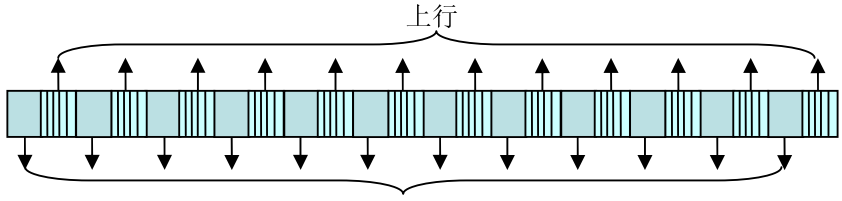

图 1 上下行时间分割

资源逐步升级速率。

TDD 的优点是十分明显的：不需要频率分割，因此在各种频谱条件下都可以灵活应用，可以更充分地利用频谱资源。这点是所有人都赞同的。

对支持 TDD，有些朋友心存疑虑：TDD 跟 EPON 全双工 MAC 层有差异，动态分配上下行带宽必然增加延时，而且 MAC 会有较大改动，因此认为不能考虑 TDD。我们认为可以采取静态分配（可配置）双向带宽（1:1 或 1:n）的方案，在此前提下，TDD 和 FDD 没有本质差异，只不过荷载的容器度量一个是频率一个是时间；工作带宽增加 1 倍（上下行 1:1）或 1/n（上下行 1:n）；因此 MAC 不需要较大改动，只不过上行时隙分配不连续，如图 1 所示，只能在

分配给上行的时间间隔内；相对于 FDD 处理速度需要提高到双向之和（影响成本）。时延也不会因为动态分配上下行带宽、频繁调度而受较大影响。这点已经有中国厂商在 HiNoC 芯片当中得到验证。

有人担心，TDD 无法中继，只适用于无源同轴网，也就是 N+0 的情景。这点确实是 TDD 不如 FDD 的地方。不过也并非无解：在主从工作模式下 RF 放大器可以由局端控制；背靠背的再生中继也是可行的，而且避免了级联指标劣化。

也有人提出，在 N+0 的情景下，FDD 也可以像 TDD 一样灵活。这点眼下是有疑问的——设备生产出来、在实际网络中部署之后，频率分割点很难随时改变；全球这么大范围，很难提供相同的频谱。例如，有人希望现在把频谱扩展到 1.7GHz，但欧洲和新加坡 950MH~2150MHz 已经被卫星中频传输占用。另外，一旦由于原有频谱不够用，需要重新规划频谱，原有的设备、特别是终端很难在新的频谱下应用。博通的 FBC（Full-Band Capture Digital Tuning）是一项非常先进、非常优秀的技术，可以解决下行通道全频段解调。但如上所述，双向灵活配置频谱需要双向频谱之和全频段解调，还需要可变滤波或更换滤波器，样机可行，我们担心的是产业化成本。

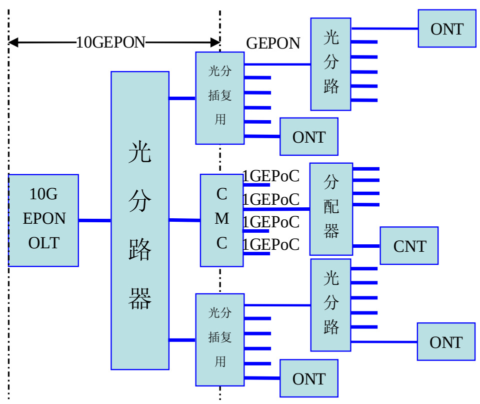

图 2 10GEPON-1GEPoC

TDD 难以解决的是相邻信道干扰（发送串扰接收），不过在 EPoC 大带宽应用条件下一般不会多信道。只有同一频段信道多个支路同时使用时（图 2 CMC 之后多个 1GEPoC 可以同频）会产生发送串扰接收，这可以用不同支路同步收发来解决，只要采用同一个时钟使各支路时间同步即可。

还有人担心同时支持 FDD 和 TDD 会使问题复杂化，会增加芯片和设备成本。同时支持两种双工技术肯定比一种复杂，但并不需要完全独立的两个 PHY，实际上可以是同一个 PHY：相对于 TDD 增加一个锁相环、处理带宽变成双向之和；相对于 FDD，下行变成了间断工作模式，但不同于上行的突发（参考图 1）。

最后，4G（LTE）就是既支持 FDD 又支持 TDD 的。

综上所述，我们认为应该同时考虑支持 FDD 和 TDD，在 1Gbps 速率级别、工作在 1GHz 以下条件下可以采用 FDD 方式，利用原有的双向放大网络（分割点上移并更换上行放大）；当升级到 10Gbps、需要把频谱扩展到 1GHz 以上时，宜采用光纤到楼的改造方式(N+0)，此时采用 TDD 比较合理。

2、关于 EPoC 目标市场

这个问题和上一个问题紧密相关，因为如果主要应用场景是 N+0，那么支持 TDD 就有价值，否则支持 TDD 就有许多新的问题。

这点在中国是毫无疑义的，广电总局提倡光纤到楼，有线运营商目前网络改造首先进行的也是光纤到楼，这就意味着 N+0。目前上海和许多东部沿海地区和一部分内地城市光纤到楼的比重已经在 80%以上，局部地区甚至已经达到 100%，全国估计可以达到 20~30%，而且这个比例还在迅速增加。据介绍，欧美有线网多数还是 N+n 的情景，但目前的网络能直接应用 10GEPoC 吗？EPoC 的目标是大带宽，这意味着高频谱占用。按照 Broadcom 目前的芯片开发计划，上行 1Gbps，下行 5Gbps，至少需要 600MHz 频谱，这在现网当中已经无法满足。如果下行扩展到 10G（对应非对称 10GEPON）或双向 10G（对应对称 10GEPON），那就更无法满足——必须重新规划频谱，并相应改造网络。问题的核心是如何改造：是光纤延伸、取消放

大器，还是改造同轴网、更换放大器？中国毫无疑问是走前面一条路的。欧美呢？我们的建议也是前者：第一，这符合发展方向；第二，总体拥有成本较低。当然，第二点需要仔细核算，不同地区会有不同结果。粗略估算一下，前者主要投入的是光缆和光缆敷设（包括接续）成本，后者主要是更换放大器，以及改变放大节距带来的接续、电缆余留（指放大器两端电缆余留）调整工程。需要说明的是，不考虑新建地下管道。如果考虑，只能说，越后建成本越高。因为如果敷设光缆需要新建管道，那迟早是要建的。更换放大器的成本大概相当于光缆的成本，而且拆除的旧电缆卖废品也可以抵消光缆成本；电缆调整工程成本和敷设光缆成本也相当，还没考虑由于放大节距缩短、放大器数量增加，原有电缆调整不过来的情况（余留需要增加，）。加上放大器耗电、维护的成本，我们怀疑第二种改造方式的合理性。即使在美国也如此。据说，美国 MSOs 希望在 N+n 网络上应用 EPoC，前提是不需要改造网络，那就只能是 1G 级别的 EPoC。当需要升级到 1G 以上时，也首先考虑 N+0。

EPoC 在中国的主要应用定位于最后一段无源同轴替代 ODN 实现相当于 FTTH 的接入。

一个标准的制定要考虑长远，不能只看 3-5 年，更不能只看眼前。光进铜退是大趋势，频谱资源日益紧张也是必然。因此应该提倡第一种改造方式，而在标准上支持 TDD。只有支持 TDD，才能满足逐步扩展频谱的需求。从中国的实际出发，更应该支持 TDD：第一，目前所有 EoC 都是 TDD 的，支持 TDD 对后期芯片支持共存有好处；第二，中国网络在 1GHz 以下应用 EPoC 机会不多，因为 5-750MHZ 已经规划并应用，750MHz 以上已经用于 EoC。不可能把原有设备一下子全部替换，原有技术和 EPoC 将会有一个长期共存的过程。因此，支持 TDD 是十分有益的，多花些代价也是值得的。

3、关于 HiNoC 与 EPoC

这是一个非常重要的因素。HiNoC 是中国 NGB 接入网标准，其目标与 EPoC 是一致的。我们强烈希望中国标准 HiNoC 跟 IEEE 标准 EPoC 统一，这对厂商、运营商都有好处，对中国、美国、欧洲、对全世界都有好处。这样可以适应更多的市场需求，而非分割了市场。但中国标准 HiNoC 要求必须支持 TDD，因此我们恳请 IEEE 充分考虑这种实际情况。

4、关于 10G-1G

在此，我们还要特别提出，需要关注图 2 所描述的应用需求：10GEPON 转换成多个 1G 支路，每个支路都可以是 EPON，也可以是 EPoC。这种应用非常有意义：第一，终端是 1G 级别，成本低廉，可以保持不变，这对运营商和用户都有利；第二，降低了 RF 处理难度；第三，频谱问题可以得到解决，因为只需要 250MHz 频谱就可以满足；第四，电信也应该欢迎，因为终端成本降低，而且升级速率不升级终端。

综上所述，支持 TDD 是符合 5 项评判准则的，是有益无害的。

最后，我们祝大会圆满成功！祝各位专家、朋友健康、快乐！

欢迎 IEEE EPoC SG 和 WG 到中国来开会！

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河南有线 周明申 王道谊

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Letter to the IEEE EPoC Study Group gathered in Minnesota

Dear Mr. Chairman, gathered experts, and friends, hello!

Insofar as China is concerned, the origins of the market opportunity for EPoC lies in the mainstream status achieved by the combination of EPON + EoC in delivering a robust and cost effective cable access scheme. In the meantime, this trend has caught the attention of cable operators internationally who are exploring ways to evolve their HFC networks to cost effectively deliver all-IP services with unified provisioning and management schemes such DPoE.

For a long time, the lack of a unified standard for EoC within China has held back large-scale deployment. The advent of the EPoC has attracted great attention in China not because of the inherent suitability of the EPON protocol or MAC to the coaxial environment but because it offers the prospect of unified management, scheduling and QoS schemes between the optical and coaxial segments of the network, and is in line with the trend toward end-to-end Ethernet/IP networks. Moreover, cable operators in China have invested great hope in EPoC as a way (perhaps the only way) that they can compete with telco FTTH deployments.

We are very pleased to see the work of the EPoC standard move forward – in particular, the discussion and formulation of the five criteria. For logistical reasons, we as a group have not been able to participate in online discussions or in person, but we have been following the developments closely. In particular, the points we have paid most attention to are:

(1) FDD vs. TDD

We have been happy to see the recent discussion regarding FDD and TDD support. This is not just a theoretical discussion, but a topic of practical importance for the cable operators in China. The support of both FDD and TDD is the way to meet the requirements of Chinese cable operators. It is understood that FDD maps most directly to the WDM scheme of optical fiber, and that it offers the advantages of dedicated upstream and downstream spectrum, including lower latency. However, the assumption of the availability of paired spectrum is not always valid, and the requirement of diplexers adds cost. Moreover, if the cost and complexity of network re-planning is to be averted, there must be sufficient spectrum up front to match the data rates on the optical segment. In the case of 10G symmetrical EPON, this would be 1.2 GHz each for upstream and downstream assuming the spectral efficiency achieved by 4096-QAM – not a realistic assumption. The advantage of TDD in this case is clear: the ability to flexibly aggregate fragments of spectrum as they become available.

What is also clear is that some people have misgivings about supporting TDD; concerns about how TDD would operate under a full-duplex EPON MAC and the increased latency inherent in a TDD system stand out. However, in a fixed up/downstream bandwidth allocation, there is no essential difference between TDD and FDD. What can be accomplished in the frequency domain with FDD is simply done in the time domain with TDD, with more or fewer timeslots assigned to the upstream. Up/downstream turnaround delays can be minimized by the aggregation of discontinuous up/downstream timeslots into contiguous blocks, as shown in Figure 1. This has been verified by the HiNOC system, which is a TDMA/TDD system.

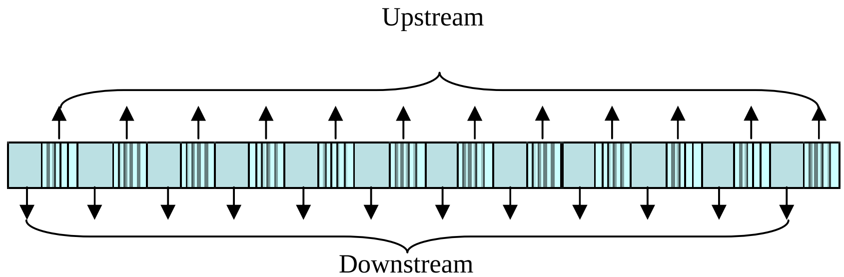

Figure 1. Up/Downstream time slot allocation

Yet others point out that TDD is only viable in an N+0 (i.e., passive) cable plant. An active cable plant is certainly a setting where FDD comes into its own. However, it is theoretically possible to operate an active cable plant in TDD mode if there were bi-directional amplifiers coordinated with the transmission schedule. It has also been suggested that FDD is equally valid and attractive in an N+0 setting. There is some doubt on that point, given the wide variety of spectrum plans in cable plants around the world (e.g., arising out of the need to avert satellite transmission bands) and the aforementioned difficulty and cost of re-planning FDD networks. Advanced technologies such as Broadcom's FBC (Full-Band Capture) are very useful in aiding spectrum re-planning. However, there still exists the problem of replacing diplexers that was mentioned before.

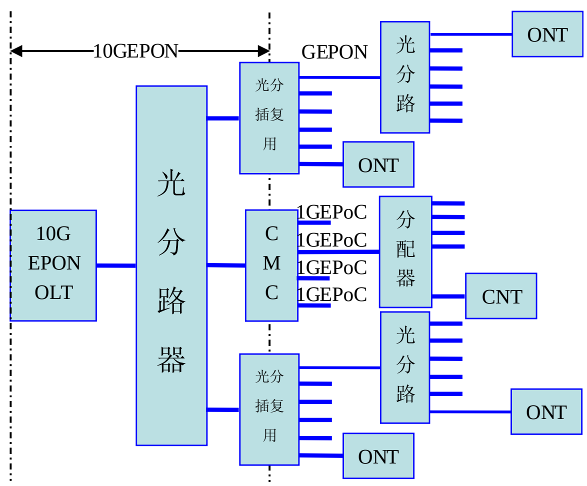

Figure 2. 10GEPON-1GEPoC

It is true that TDD would introduce problems of adjacent channel interference (i.e., receiver saturation) given unsynchronized transmissions schedules if EPoC channels were co-located (as depicted in Figure 2, in the segment to the right of the CMC). However, given the large bandwidths involved in EPoC channels, it is unlikely that they would be so co-located. Moreover, there always exists the option of synchronizing up/downstream transmissions.

There is then the concern that supporting both FDD and TDD will complicate the standard and increase the cost of devices and end equipment. There is certainly incremental complexity introduced in supporting both duplex modes, but also a significant degree of commonality and shared resources as well. There is essentially one PHY; whereas TDD mode adds a PLL relative to FDD, it can be essentially understood as a subset of the FDD mode of operation (reference Figure 1). It is worth mentioning that 4G LTE supports both FDD and TDD modes of operation.

To summarize, we should consider supporting both FDD and TDD modes at the 1 Gbps service level, which will utilize spectrum below 1 GHz, which is largely amplified. However, in the expansion toward 10 Gbps service levels, which will utilize the spectrum above 1 GHz which is largely unamplified, TDD seems like a reasonable choice.

(2) The Target Market of EPoC

This topic bears close relationship to the prior question of duplexing scheme, as it is predicated on the nature of the target cable plant. If the main scenario is N+0, then TDD is appropriate. If the plant is active, there may be problems with TDD. There is no question as to the direction that China is heading, as SARFT has been aggressively promoting and deploying fiber to the building or curb. In Shanghai and other coastal provinces, the percentage of FTTB or FTTC deployment has reached 80%, or in some cases, 100%. It is widely held that the majority of cable plant in N. America and Europe is of the N+n variety. The question is how applicable the Chinese situation is to the cable evolution in N. America and Europe.

A distinguishing trait of EPoC is its support of high data rates, which means correspondingly large spectral occupancy. If we take Broadcom’s chip development plan as an example, a minimum configuration of 5 Gbps downstream and 1 Gbps upstream implies a spectral occupancy of at least 600 MHz, which no existing network can accommodate. Extension of data rates to 10 Gbps in each direction will only reinforce the need for network reconditioning. The question is how? Extend the fiber, run it to the last amplifier, or replace the amplifier? There is no doubt that China is out in front on this account.

In the existing N+n cable plants of N. America and Europe, there are many unanswered questions about how the plant will be reconditioned to support EPoC. Replacement of taps, splitters, amplifiers? In the case that the plant is not reconditioned, maximum data rates may top out at 1 Gbps, in which case the use case of EPoC is limited. We believe that only in the context of multi-Gbps data rates does EPoC make sense, since only then is it future proofed against the encroachment of FTTH deployments. This almost certainly implies the deployment of EPoC into N+0 plant, where TDD provides the maximum flexibility.

The situation in China requires the support of TDD. First, all existing EoC networks operate in TDD mode. Having EPoC support TDD will ease the transition of EoC into EPoC. Secondly, EPoC will have to initially operate in spectrum above 1 GHz. 5-750 MHz is already fully occupied by existing applications, and 750-1 GHz has been allocated for EoC (HiNOC). Given the wide availability of N+0 cable plant in China with the ability to support operation above 1 GHz, the incremental cost and complexity of including TDD support in EPoC is well worth the future proofing that TDD delivers.

(3) HiNOC and EPoC

The relationship between HiNOC, the indigenous Chinese Next Generation Broadcast (NGB) cable access standard, and EPoC is an important factor to consider in crafting the EPoC standard. We strongly believe that harmonization between EPoC and HiNOC would be highly beneficial to the global industry, as the possibility of having chipsets that support both EPoC and HiNOC would lower costs for the entire supply chain, right on up through to the operators. The HiNOC standard is TDMA/TDD, a fact which we hope will be taken in account in the IEEE.*

* Translator’s note: HiNOC has been submitted to ITU-T Study Group 9 for global standardization.

(4) Regarding 10G-1G

At this point, we would like to revisit the scenario depicted in Figure 2, namely that of one single 10G optical pipe being divided into multiple 1G pipes (whether optical or coaxial) as we move deeper into the distribution network. We believe this is the most realistic and attractive deployment scenario for EPoC, because it allows for a mixed deployment of ONUs and CNUs, all of which are 1 Gbps-caliber customer premises units, which should: (1) Lower costs as 1G ONUs are also in demand by the telcos, and (2) Lower spectrum requirements on the coaxial segment to 250 MHz in 1G symmetric operation. This scenario should be in line with the five objectives that are under consideration in the study group.

We hope to have the opportunity to host the IEEE Study Group in China in the near future.

We wish you a very successful meeting in Minneapolis! Health and happiness to all!

Sincerely yours,

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Henan Cable TV Network Group CO.,LTD Zhou Mingshen; Wang Daoyi
Jiangsu BC & TV Information Network CO.,LTD XuRugang ;Gao Xiaojun
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SARFT National Labs for Digital CATV Application Technology Li Mengling
Technical Working Committee of China Radio & TV Association Yao Yong; LiaoYugong
Huawei Fang Liming; Hesham ElBakoury
ZTE Sun Chang
Fiberhome Zhou Zhen
YOTC Hu Baomin
Haier Dai Shusheng; Qiang Hui
Guangxin Technology Co. Yu Yang
Laketune Li Kemin
Wuxi Lutong Xu Lei ;Yin Guanmin
Qualcomm Alex