Meeting the Challenges of High-Capacity Indoor and Outdoor Coverage

The Perspective from WiMAX Operators

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WiMAX promises to bring wireless broadband anywhere and anytime, on laptops, phones, game consoles, cameras and new mobile devices. Subscribers increasingly use bandwidth-heavy applications like video streaming and they do so mostly from indoor locations such as malls, classrooms, offices and homes.

What are the implications for WiMAX operators from the prevalence of wireless broadband access from indoor locations? Do WiMAX operators need to provide indoor coverage to meet the demand from their subscribers? And if so, is deep indoor coverage needed? Do they need to provide indoor coverage at launch or can they wait? What is the best approach to provide such coverage for the traffic levels expected?

We conducted a survey of leading WiMAX operators worldwide to explore their experience to date and their future plans. Despite the differences in business models, services offered and market demographics, most operators share a sense of urgency when it comes to providing robust indoor high-capacity coverage. They are actively looking at cost-effective approaches to go beyond their initial deployments which almost exclusively target outdoor coverage.

Key findings from the WiMAX operators survey

- Coverage of indoor locations and high-density areas has become a top priority early on
- Macro base station deployments will not satisfy indoor coverage and capacity requirements
- Many operators are ready to deploy microcells and picocells as solutions that lower capex and opex and that are spectrally efficient
- Microcells and picocells will form underlay networks that will complement the wide area coverage provided by macrocells

Introduction

As WiMAX operators move to full-scale trials and commercial deployments, they are gaining precious information about subscriber experience, network performance and coverage in loaded networks. To get an insight into how the leading WiMAX operators worldwide approach two key issues—indoor coverage and high-density traffic demand—we conducted a survey of 24 advanced and innovative WiMAX operators, with deep experience, a strong market presence and extensive network deployment plans. We included operators from all geographic regions, with a variety of spectrum assets, technology deployments and business models (Figure 1).

In a previous paper entitled "Planning for enhanced indoor coverage and high capacity in WiMAX networks" (August 2007; available at www.senzafiliconsulting.com), we discussed the challenges that WiMAX operators face. In this paper we report on their experience to date, and their future plans and expectations.

The overall results of the survey suggest an urgent need to provide high-capacity coverage in indoor locations, where most subscribers will use their fixed or mobile broadband connection. The macrocell infrastructure that dominates in initial rollouts will not be sufficient to support heavy indoor usage and operators have started to plan a move away from a network topology dominated by macrocells, and towards a wider range of base station types to address indoor coverage and high capacity-density requirements.

Each operator we talked to has a very unique set of requirements. We expect this to drive the development of a diverse set of network topologies that have the flexibility to meet the operators' requirements. These solutions may include microcells to boost outdoor coverage and capacity; microcells and picocells to provide indoor high-capacity coverage; and femtocells to offer indoor coverage to residential and small business users. This underlay network allows operators to offload most of the traffic from the macro network.

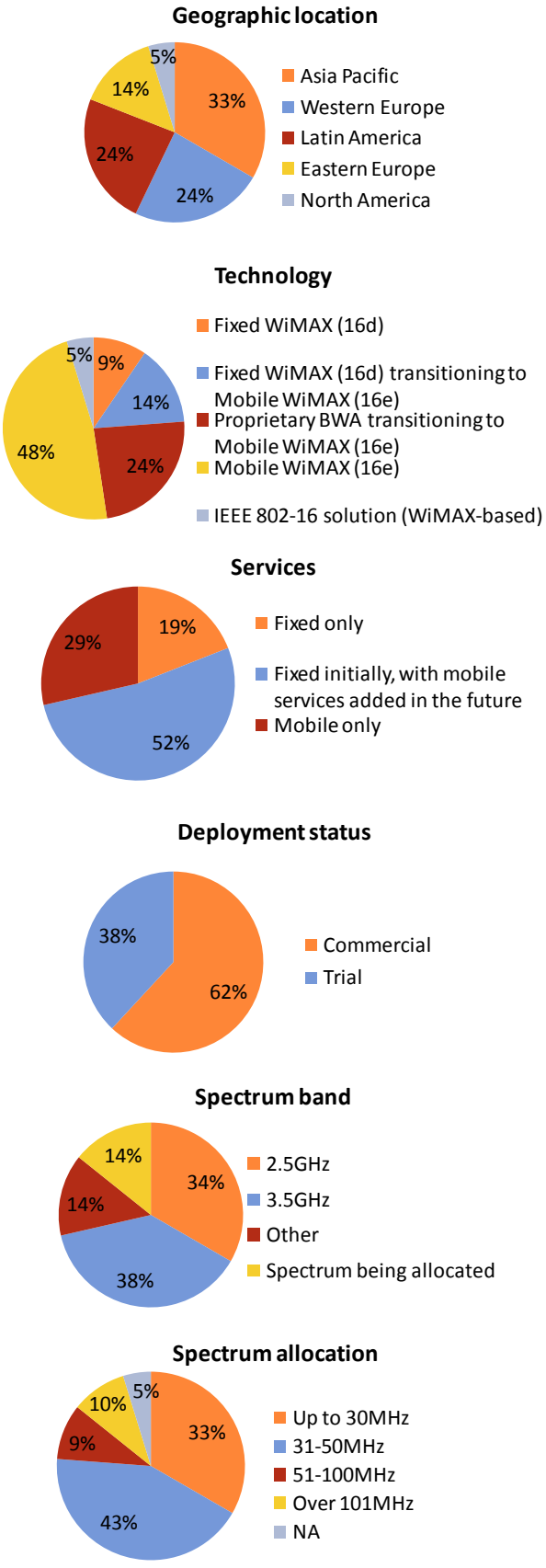

Figure 1. WiMAX operators surveyed

The experience to date of surveyed WiMAX operators

Most operators surveyed focused their initial network deployments on consistent outdoor coverage across their markets, as well as basic first-wall penetration to reach indoor customers. In urban environments, cell ranges rapidly shrink from 1 to 1.5km (pure outdoor coverage) to an average of 400-500m to achieve just basic indoor coverage. This is due to an average loss of 15-16dB for first-wall building penetration (Table 1).

Some mobile operators planning WiMAX deployments may decide to focus exclusively on limited outdoor or indoor areas with high demand for mobile broadband access.

Operators are generally satisfied with the outdoor coverage of their WiMAX networks or with the coverage projections based on their trials. What they are finding is that most of their subscribers cannot take advantage of this, as they are mostly indoors where coverage and throughput are limited.

Operator metrics and assumptions	
Indoor loss (first wall indoor)	15-16* dB
Urban cell range (first wall indoor)	400-500* m
Indoor traffic	Over 80% for 75% of operators**
Frequency reuse	73% of operators** use 1:1
Average traffic per connected subscriber	32-37 kbps*

* Median across operators who provided the information

** Where operator information is available

Table 1. Operators' metrics and assumptions

As soon as their coverage targets are met, operators quickly realize that indoor coverage is the next step.

Traffic requirements will grow quickly as new subscribers sign up and operators expect that their networks will be operating at full capacity in the next few years. When their networks become capacity-constrained, operators need to deploy additional base stations to transport subscriber traffic.

The importance of indoor coverage

The majority (86%) of the operators surveyed consider indoor coverage a necessary component in their product offering (Figure 2). The reason for this is simple: 75% of operators estimate that over 80% of their subscribers will connect to the WiMAX network from indoor locations.

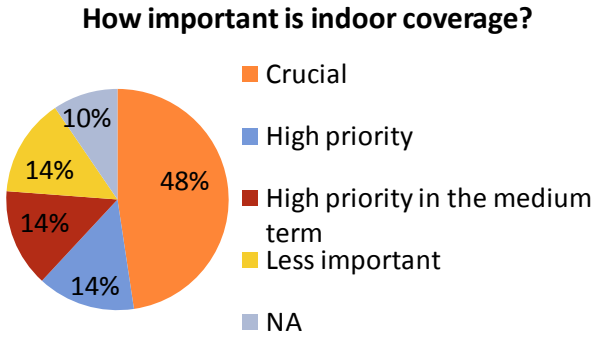

Figure 2. Importance of indoor coverage

In the initial phase, this may not be surprising as fixed connections with indoor modems are dominant. However, operators do not expect indoor usage to decrease significantly with the adoption of mobile devices. Most data applications, especially if involving a video element, often require the subscriber to be in a stationary position, preferably seated, in an environment where glare or bad weather do not disrupt the

experience. In most cases, this means an indoor location.

Support for mobile services will require more than first-wall indoor coverage. Fixed WiMAX operators expect their subscribers to accept indoor coverage limitations and to position the desktop modem next to a window facing the base station to get better channel conditions. Mobile subscribers are unlikely to accept such limitations as they expect a level of coverage comparable to that of cellular networks.

Most of the surveyed WiMAX operators indicated that the current level of indoor coverage was not sufficient to meet the demand for mobile access and that they were looking at cost-effective solutions to provide indoor coverage, either through outdoor microcells targeting neighboring buildings or though indoor picocells.

The growth in traffic requirements

In the early stages of deployment, operators have only a limited number of subscribers. While WiMAX networks are not yet capacity-constrained and can accommodate additional traffic, many operators voice concerns about how they will meet future demand, on the basis of usage levels they see and the traffic levels that their networks can support.

On average WiMAX subscribers use 32-37kbps when they are online—a figure that is in line with usage levels for other broadband access technologies. Downloads and video applications (e.g. from YouTube) are widely expected to drive higher per-user traffic requirements in the future. The ability to share subscriber-generated video content in real time will increase the attractiveness of the services, but it will also generate substantial traffic. Operators have started to worry about subscriber-generated uplink traffic, especially from mobile devices, as it uses more network resources than downlink traffic.

Some operators plan to offer and promote IPTV, video calls, video conferencing and streaming, but this will be difficult to do unless they have large spectrum allowances (e.g. over 50MHz) and they deploy a dense network of base stations. In our survey only 19% of operators have control over 50MHz of spectrum.

Most operators have not yet developed a strategy to cope with the need for additional capacity. They all agree that a higher density of base stations will be needed, but many would like to avoid the addition of macro base stations as this can become progressively more expensive[1]. They have started to explore alternative network topologies that include an underlay network of microcells and picocells.

The transition to mobility

WiMAX operators start with fixed or nomadic access (i.e. where the subscriber can connect from any location, but is stationary while connected) as mobile devices are not yet available. However nearly all WiMAX operators plan to expand their services eventually to include full mobile access.

Mobility requires much more than support for handoffs and operators are becoming increasingly aware of the challenges they will need to face. “Network optimization is much more difficult for mobile access, because we do not know from which locations subscribers will connect,” Krassimir Stoitcheff, CEO, at MAX Telecom (Bulgaria) says.

With mobility, indoor coverage becomes even more crucial. Smaller, low-power mobile handsets are likely to use less favorable modulation schemes from in-building locations than desktop modems. This results in lower data rates and the need to reserve more network resources for indoor users with mobile devices if macrocells are used.

1 . Higher base station density leads to higher levels of interference and hence lower capacity on a per-base station basis. Furthermore, site acquisition may become considerably more expensive when the operator has to locate the base station within a very limited area and this is the case when base stations are in close proximity.

Deep indoor coverage is needed to meet the demand from mobile users within large buildings (e.g. office buildings, covered malls, hospitals). The macro infrastructure—either for WiMAX or cellular technologies—is not well suited to provide consistent deep indoor coverage.

Base station options

What choices are available to operators when they realize they need to deploy new base stations to improve indoor or outdoor coverage or increase their network capacity?

Macrocells. In the initial stage of virtually all WiMAX deployments to date, macrocells are the first network element to be deployed. They typically have multiple sectors and this enables operators to aggregate high levels of throughput within a single cell site location. Macrocells are the base stations with longest range, but are also the most expensive to purchase, deploy and maintain, as they have demanding power and site installation requirements.

While macrocells are a cost-effective solution for establishing initial outdoor coverage, they are often too expensive and inadequate to address coverage holes, to provide indoor coverage and to handle high levels of traffic demand in high-density urban areas and from inside buildings.

Microcells and picocells in an outdoor environment. Outdoor microcells and picocells are smaller and less expensive than multi-sector macro base stations. They typically have a more limited range and, if they have a single sector, also limited capacity. They are typically used in high-density urban areas with a high concentration of users and traffic. They can be deployed in dense networks, where each cell covers a small area, ensuring good coverage and high capacity density. They can be located on lampposts, rooftops, or on building walls and, as they are in close proximity to buildings, they can be very effective at providing indoor coverage. Microcells and picocells may use wireline or wireless backhaul. Mesh topologies may be adopted where wireless backhaul is fully integrated into the base station.

Picocells in public indoor locations or within enterprise buildings. Indoor solutions are often the only way to provide deep in-building coverage. They are smaller than microcells and outdoor picocells, and their cost and ease of installation is even lower, as they can be mounted on walls or ceilings. Picocells can use wireless or wireline backhaul, depending on the availability and cost of the connectivity options available. Inexpensive wireline broadband links, where available, often prove to be the most cost-effective solution. But in buildings where suitable wireline connectivity is not available or is too expensive, wireless backhaul can be used instead. Furthermore, some picocells can use wireless backhaul to send their traffic to other nearby picocells to form a small mesh network that can aggregate traffic to the nearest location where wireline backhaul is available.

Femtocells. Self-installable, low-cost femtocells can be used to improve coverage in homes or small businesses. Subscribers typically purchase them from the operator or directly from a retail store and install them without any assistance from the operator.

Microcells, picocells, and femtocells can use both wireline and wireless links for the backhaul, depending on the cost, availability and scalability of different solutions. In particular, they can support in-band backhaul to enable operators to use their spectrum holdings to carry backhaul traffic to the nearest macro base station or to the nearest microcell or picocells with wireline backhaul. The IEEE 802.16j standard will support a relay architecture that will allow operators to use in-band wireless backhaul while retaining all the standard WiMAX functionality and performance.

Within the macro network, microcells, picocells and femtocells may be deployed to create an **underlay network** that enhances the overall indoor and outdoor network coverage and delivers on required capacity density. Operators will select a variety of approaches in the selection of microcells, picocells

or femtocells according to their specific requirements.

Macro infrastructure limitations

Operators view macro base stations as the basis of the network that gives them the initial geographical coverage needed to launch the service. With a few exceptions all operators concentrate on macro base stations to quickly obtain market coverage and to minimize the initial capital outlay.

As they do so, however, they increasingly try to limit the number of new macrocells installed and to explore cost-effective alternative solutions to address their increasing coverage and capacity needs.

There are several reasons for this. The cost of the macro infrastructure is often cited as a concern. While base station prices are expected to get lower as sales volumes grow, installation and operational costs are technology independent and remain high. In most markets, deployment costs typically exceed those for base station hardware.

Access to macro base station sites is another issue. Mike Stacey, CTO at Irish Broadband (Ireland) notes that "Securing new locations for macrocells is becoming increasingly difficult and may cause delays and increased costs. In some cases available sites are not suitable due to interference issues that could be caused by co-location."

Permits are typically necessary and some municipalities require a lengthy process to authorize the installation of new antennas. The problem is particularly acute for greenfield operators, as they do not have access to an existing network of base stations they can leverage.

Adding more macro base stations to enhance indoor coverage to the desired levels can be quite expensive for operators that have coverage-driven deployments. In most cases, this is also an approach that quickly leads to diminishing returns, especially among those operators that use a frequency reuse of 1:1 (73% in our sample) and have adjacent base stations using spectrum channels in the same frequency. A higher density of macro base stations leads to higher levels of interference, which in turn reduces base station capacity and return on investment. "Simply adding new macro base stations is unlikely to increase capacity to the desired levels, as the resulting interference is likely to reduce the throughput from each base station," José Luiz Frauendorf, Executive Director at Neotec (Brazil), says.

New network topologies

There is wide agreement among operators that the macro infrastructure is not sufficient to address their coverage and capacity requirements and 76% of them plan to deploy an underlay network (Figure 3).

In these new network topologies that use underlay networks to ensure indoor coverage and capacity, microcells and picocells have emerged as the most important elements in the short to medium term, with femtocells becoming more attractive at a later stage, as adoption of mobile devices reaches a critical level.

Cost reduction in site acquisition and rental, in hardware purchase and installation, and in backhaul are the main benefits that operators expect from microcells and picocells.

Given the current price levels for microcells (US$4,000 or more), many operators are not sure that they represent a cost-effective solution. However some operators have adopted or plan to adopt microcells at these price points because they represent the only solution available.

If easy-to-install and compact base stations with limited power requirements were available below the US$1,000 price range, operators say they would be more likely to direct a larger portion of

their infrastructure investments towards compact base station deployments.

While they agree that an underlay network is necessary, operators indicate that they are still unable to develop a strategy for its deployment because of current limitations in the price and functionality of commercially available solutions.

Backhaul considerations play an important role when planning for the deployment of an underlay network. The increase in the number of base stations increases the number of backhaul links needed and, if wireline backhaul is used, the operating costs can quickly escalate.

Incumbent operators with easy and inexpensive access to an extensive fiber optic or DSL network prefer to use wireline backhaul where available.

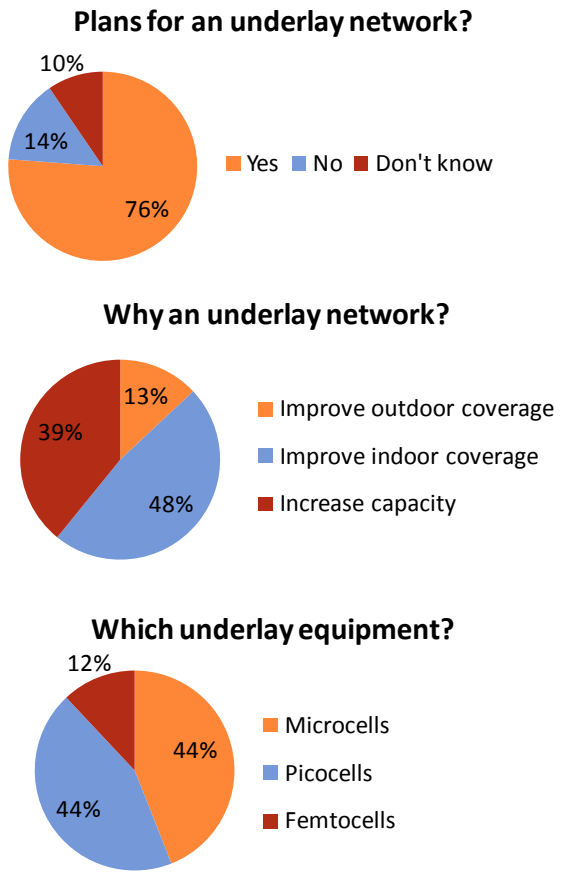

Figure 3. WiMAX operator plans for underlay networks

Most WiMAX operators, however, do not have easy access to wireline backhaul. In some countries, the wireline infrastructure is limited and access to fiber or DSL backhaul may require lengthy negotiations with real estate managers. Even where wireline infrastructure is widely available, it is often owned by a competing operator that may impose unfavorable pricing or conditions or that may limit the WiMAX operator's control over network performance.

For these operators, wireless backhaul is the preferred solution, if not a straightforward requirement. In-band backhaul that uses the same spectrum for both subscriber access and backhaul to the nearest macrocell or the closest picocells or microcell with wireline backhaul is the easiest and often most cost-effective solution to implement, as it does not require any additional hardware or spectrum allocation. "We are exploring in-band wireless backhaul solutions within a dense underlay network of picocells and microcells. This will enable us to improve indoor coverage and to provide high data rates to our subscribers in a cost-effective and efficient way," James Lin, Assistance Vice President at Fitel (Taiwan), says.

However operators with limited spectrum allowances worry that in-band wireless backhaul may impose a heavy overhead that will limit the overall network capacity used to support subscriber access.

High spectral efficiency in the in-band backhaul is expected to lead to a significant overall increase in capacity in the combined macrocell and underlay network when compared to the macro infrastructure alone. This can be accomplished by picocells and microcells that create islands of high capacity coverage where devices can use efficient modulation while offloading traffic from the macro network. In turn, microcells and picocells aggregate local traffic and can backhaul it using a dedicated, more efficient backhaul channel to the nearest base station with wireline backhaul. Furthermore, underlay base stations can form local interconnected clusters using a mesh topology to reduce costs and requirements for wireline backhaul.

Conclusions

Indoor coverage and high capacity density have rapidly become hot topics. In our survey, WiMAX operators have indicated they are ready to move beyond a single-tier macrocell network topology to address the coverage and traffic requirements of their fixed and mobile subscribers.

The need for dedicated infrastructure for indoor coverage is not a WiMAX-specific requirement and LTE operators will face the same challenges to reach in-building locations. WiMAX will follow an evolution path similar to that of cellular technologies. In 3G deployments there has been an increasing emphasis on infrastructure specifically targeted to improve service quality and capacity in indoor environments. In countries like Japan, for instance, the initial macrocell deployment of 3G infrastructure was quickly followed by a much more focused deployment of microcells and picocells in urban, high-density areas.

WiMAX operators have started to explore how they can deploy an underlay network that may include varying configurations of microcells and picocells in outdoor environments, and picocells and femtocells in indoor environments. Their efforts to diversify their network architecture will accelerate as mobile device adoption grows.

"The business case for mobile devices simply does not work within a macro-only infrastructure", says Eric Hamilton, CTO at Unwired (Australia). "A layered architecture approach that combines macrocells with smaller, cheaper and low-power cells has to be adopted to support subscribers that will be mostly in indoor locations, using devices with small antennas and bandwidth-intensive applications, like video streaming".

Femtocells are more likely to become more prominent at a later stage when adoption of WiMAX mobile devices reaches a critical level. The demand for microcells and picocells is much more urgent as they address immediate coverage and capacity issues.

Based on feedback from operators, we expect their capital expenditure in the underlay infrastructure to grow quickly over the next years, as solutions become commercially available and equipment costs decrease. If we project that 25% of base station capex is devoted to microcells and picocells, global equipment revenues for the underlay infrastructure will reach US$1.2bn by 2012 or 9% of total equipment revenues (including devices, base stations, and core network equipment, but excluding femtocells).

However, operators are still unable to develop a detailed underlay network strategy as there is only limited commercial availability of solutions and these still fall short of meeting their cost targets and feature requirements.

As it is still early days in the deployment of WiMAX, it is not surprising that the main market focus is still on the macro infrastructure. Both vendors and operators are still working on their initial rollouts and are trying to ensure that performance targets are met and WiMAX functionality is supported as expected.

At the same time, however, it is clear that the WiMAX path to mobility will require an additional underlay network of microcells, picocells and femtocells that will bring to the market the ubiquitous mobile broadband experience that subscribers demand.

About DesignArt Networks

DesignArt Networks Ltd. is a fabless semiconductor company driving the evolution of the 4G wireless network infrastructure, towards high-density, high-capacity deployments with ubiquitous and uniform out- and indoor coverage. DesignArt provides a comprehensive WiMAX System-on-a-Chip (SoC) silicon platform, with the goal of substantially lowering the cost of the WiMAX network infrastructure. Based on DesignArt's patented single-chip design architecture, this SoC platform enables equipment vendors to build a portfolio of base and relay stations, ranging from microcells, picocells to femtocells and multi-service access point designs. DesignArt combines an experienced management team with strong technology leadership, and holds a unique combination of expertise and intellectual property. For more information about DesignArt Networks, please visit www.designartnetworks.com.

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Senza Fili Consulting provides advisory support on wireless data technologies and services. Our expertise extends to cellular communications, WiMAX, Wi-Fi, and other fixed and mobile broadband wireless access technologies. We assist vendors in gaining a better understanding of the service provider and end-user markets. We work alongside service providers in developing a wireless data strategy and in assessing the demand for wireless services. Independent advice, a strong quantitative backing, and an international perspective are the hallmarks of our work.

At Senza Fili we have in-depth expertise in financial modeling, market forecasts and research, business plan support, due diligence, white paper preparation, training, and evaluation of end-user requirements. Our clients are international and span the entire value chain; they include fixed and mobile operators, ISPs, wireless ISPs, other service providers, vendors, solution providers, system integrators, investors, and industry associations.

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