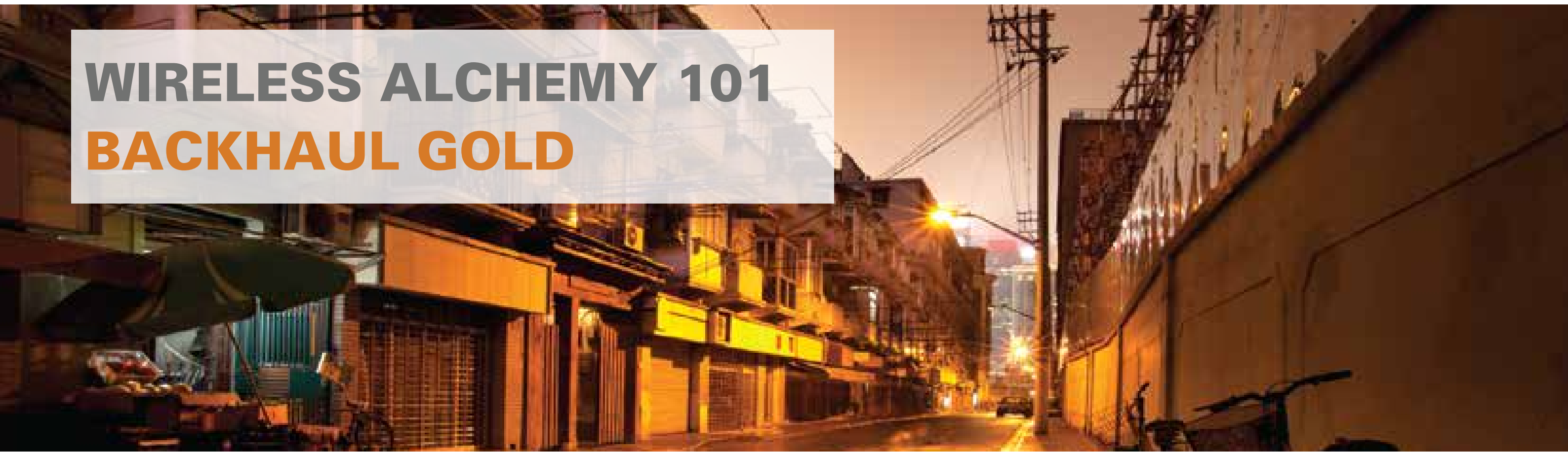
GENESIS
TECHNICAL SYSTEMS



WIRELESS ALCHEMY 101
BACKHAUL GOLD

Turning telecom copper into backhaul gold

Next Generation wireless networks (4G/LTE/LTE-Advanced) are being based on the premise of 100 Mb/s data transmission to the handset. Imagine being able to live stream 1080P HD video to your device any time, anywhere, even as you are travelling by car (though not while in the driver's seat), bus, etc. Sounds like a great idea and many consumers don't understand why this isn't universally available right now at a reasonable price.

How do we make this happen?

The wireless industry has worked persistently on getting the 3G standards, equipment & networks deployed and functioning, but high bandwidth applications like streaming HD video are generally beyond what those standards, equipment and networks were originally designed to handle.
The obvious first thoughts are along the lines of:
"Can't you just put new, faster radios in the 3G networks to achieve 4G speeds?"
Sure you can...but only to an extent.

3G networks are based on fairly large antenna base stations (BTSs). In much of the world, BTS sites have all been upgraded with fibre optic network connections to be able to handle the more than 10x bandwidth/handset that 4G networks demand. Unfortunately, that is not the whole story. If you take a 3G BTS site, it could handle a maximum bandwidth (limited by the combination of the speed and spectrum of the radios and the speed of the backhaul connection to the network) of perhaps 100 Mb/s with a fibre network connection and cover an area of perhaps 15-30 square kilometers.

This means that all the wireless devices within the 15-30 square kilometers can share that 100 Mb/s.

In a downtown city core that capacity is exhaused very quickly and everyone gets very little bandwidth. If one of those people is using a device that needs all of that 100 Mb/s bandwidth, then it is not available to anyone else. You can see that the current 3G network architecture will simply not work for high bandwidth applications on any commercial scale. To achieve 4G speeds would generally require between 4-10x the number of 3G BTS sites. Given that each of those sites costs anywhere from $50,000 to $250,000, depending on the distance that the fibre has to be laid to reach it, you can see that this architecture is now non-economic.

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Mobile data usage explosion

The rapidly accelerating consumption of mobile data is being driven by consumer adoption of smart phones, wearable devices and mobile-connected tablets, in parallel with 3G and 4G deployments.

Cisco's VNI Mobile Data research found that that global mobile data will increase nearly 11-fold between 2013 and 2018, with traffic growing at a compound annual growth rate (CAGR) of 61 percent from 2013 to 2018, reaching 15.9 Exabytes per month by 2018.

Whilst operators are keen to realise content and delivery revenues associated with mobile data growth, they recognise the challenge of developing networks that can accommodate future consumer demands.

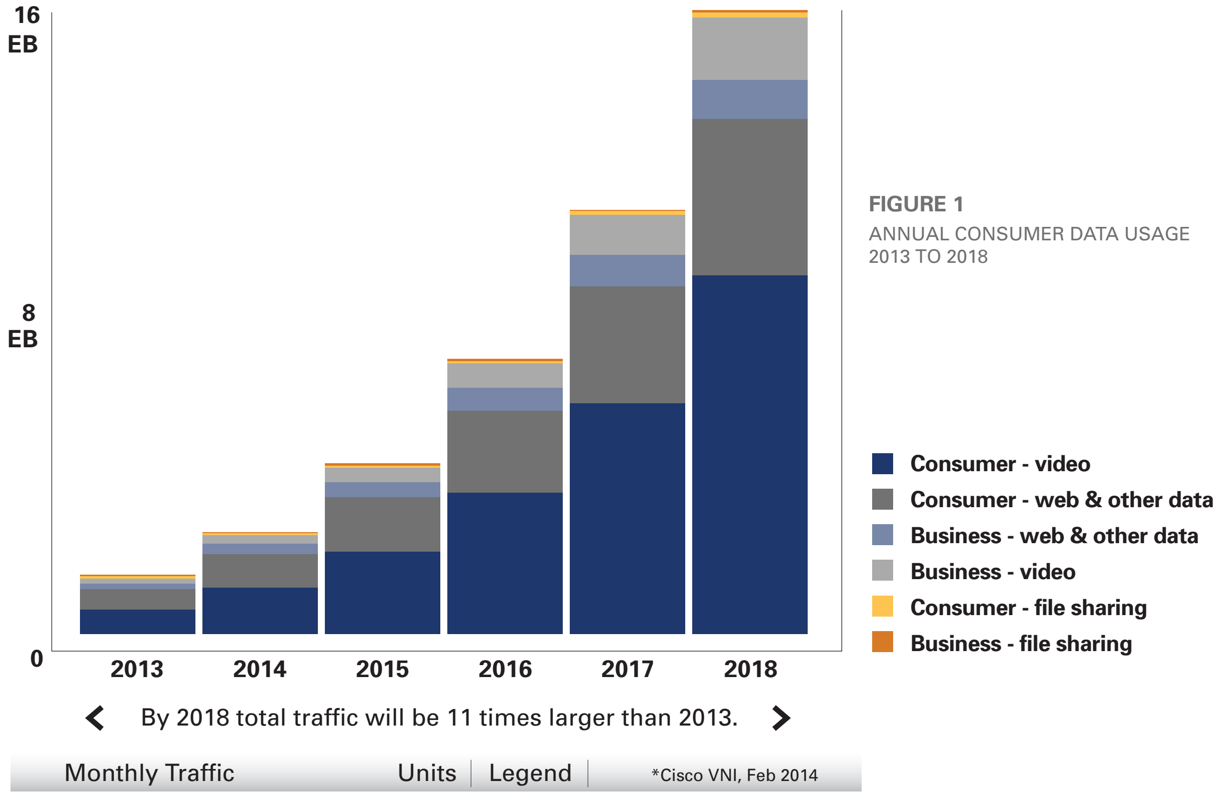

FIGURE 1
ANNUAL CONSUMER DATA USAGE 2013 TO 2018

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If the 3G wireless network architecture won't work, how do we get to universal 4G availability?

The wireless industry has made a lot of progress since the original 3G standards were developed and 4G standards have been written and passed by international technical experts. The approach is to produce smaller BTS sites that are less expensive to deploy, are physically small with a smaller footprint, and have much lower transmit power, so that they cover a much smaller area. There would also need to be lots of them, perhaps up to fifty times more small sites than there are current BTS sites.

These sites go by the names of microcells, femtocells, picocells or just small cells for short. The idea is that these small cells can be put almost everywhere to offload the BTS sites (called macrocells). In the future it is likely that the wireless networks that we use will be almost entirely based on small cells with the macrocells (BTSs) being used to 'fill the gaps' either between the small cells or in suburban and rural areas where the population density is lower. These small cells would be designed to handle perhaps 20-50 simultaneous users with a backhaul connection speed of 10-100 Mb/s.

The following needs to be considered when thinking about small cells.

- **Physically small:** This is necessary as the goal is for them to be inconspicuous and placed on store fronts, lamp posts and road signage, etc.

- **Low cost:** The sheer number of them that need to be deployed is much larger than the number of macrocells (BTSs) deployed for 3G networks.

- **Low transmit radio power:** Having a large number of high power transmitters in any given area will cause large amounts of interference with each other. Lowering the power means that the mutual interference is reduced and easier for mathematical interference cancellation techniques to handle within the capabilities of the low cost radios that need to be used.

Backhaul bandwidth: As all communication with handheld devices is via the network, which provides the foundation of the Internet, the higher the bandwidth available to the small cell, the more simultaneous devices that can be supported by that small cell, and the fewer the number of devices that have to be handled by the macrocell network.

- This can be achieved by using both interference cancellation and bonding techniques depending on the situation - there is no one size that fits every situation unfortunately.

- These technologies attempt to move the point at which the network is shared closer to the user, so that every user benefits from being able to use any available bandwidth.

- **Availability of small cell power:** The small cells need electrical power to be able to transmit their radio signals and to connect to the rest of the wired network. A source of electrical power is essential for any modern communications system.

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So what are the options for small cell backhaul?

There are many wireless backhaul-based solutions that need little more than a power source - in theory. They involve getting the traffic (voice, video & data) from one set of frequencies and putting them on another, generally unlicensed and less costly part of the spectrum. As the number of small cells increases, this creates more problem than it solves as you are just moving things around within a finite number of radio carriers whose regulations will change from country to country.

A number of powering options need to be considered. Generally the interface at the base of the antenna is Ethernet which then feeds into a wired communications medium that takes in Ethernet packets and maps them into whatever protocol is used on that medium (e.g.: fibre may use SONET/SDH, xPON, Gigabit Ethernet, etc. and copper-based connections may be T1/E1, DOCSIS cable or xDSL-based). There is generally a lot of processing that takes place in BTS sites to cancel and/or compensate for interference, correct errors, manage the site, etc.

Many companies are concentrating on separating that processing from the physical antenna by putting fibre up the mast to the actual MiMo grid (fronthaul) and combining that processing power in a single site. However this needs fibre to be deployed to smaller, more power efficient sites which is often economically questionable due to the number of sites that will need fibre connectivity.

Optical fibre-based systems can carry the most data, but are not physically deployed in the vast majority of locations that might need small cells. This means tunneling under roads, through gardens, etc. and that takes lawyers (to get the rights of way to do this), backhoes, cable pullers, etc. and a lot of time to get things in order.

There is a lot of copper wire around to all those old telephones that we used to use. Is there some way we can re-use all that?
Of course there is! In fact, in discussions with major telecom carriers, some have said that they will not deploy optical fibre to support small cells as there is simply too much fibre that would be required and it would be uneconomic per small cell. Each cell has to make a profit on its own for the operator to want to put it there and power it.

As there are fewer people using each small cell the installation has to be economical, the equipment low-cost, and the access to the electrical power has to be affordable. Copper is a good electrical conductor so could be used as a part of a powering strategy as well. So called 'line powering' has been around since the invention of the telephone and could be used to power small cells as well as multiplexing equipment - within reason.

By using the same technology that provides household Internet access over telephone wires (Digital Subscriber Line or DSL - the latest version is VDSL2 which is capable of delivering up to 100 Mb/s over a single copper wire pair over short distances) and using the previously mentioned bonding approach (taking multiple

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pairs and combining their bandwidth so that a single large pipe can be realised) it is possible to power and provide significant amounts of backhaul bandwidth to small cells.

Copper is already deployed in telecom networks and has been for many years. Today there is often spare capacity (basically spare copper pairs that are part of a cable bundle deployed to serve a group of subscribers such as a small number of houses, apartments, or shops) but generally not enough to maximise telco revenue on their own. Deploying more copper cabling would cost almost as much as laying optical fibre - which telcos have already told us is uneconomical. So the answer has to be that we 'share' the cabling that currently serves the people it was originally deployed for.

What would this copper backhaul solution look like?

Small cells need to be deployed close to where consumers use their mobile phones and mobile phone use within the home is increasing rapidly. We have already stated that there is generally insufficient spare capacity in the deployed copper infrastructure to achieve maximum revenue from small cells, but if we combine the bandwidth carrying capacity of the people currently being served by that infrastructure, it is definitely possible. This suggests:

- A small cell is an electrically powered, or 'active' piece of equipment that would be deployed near the homes of subscribers as this is where the bandwidth is needed.

- Electricity needs to be supplied to that small cell over the copper wiring from either the network, the households served with Internet access over that copper, or both. A good delineation might be that the network provides sufficient power to keep the small cell going at all times but the households provide the additional power required for the wired Internet access.

- Traffic bandwidth needs to be delivered to the small cell that is combined with the Internet access that existing subscribers are already paying for - it would also be nice to give the Internet access customers a boost in performance as well. Bonding handles this well.

- Given that we are combining traffic that has differing 'priorities' (e.g.: voice calls are generally more important than web surfing and emails), some level of Quality of Service (QoS) needs to be considered.

- Interference cancellation on the copper (vectoring) should be considered as part of the package but its benefits are generally lost after about 1km from the DSLAM and may never be realised if a Local Loop Unbundling (LLU) situation exists in the network.

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Powering considerations

How much electrical power would be required to power the small cell and this household Internet access multiplexing equipment?

The small cell has a more or less fixed amount of power that it will consume to provide coverage over a given physical area. This means that the multiplexing equipment has to be flexible enough to terminate a bunch of DSL lines from the network, drive those network lines with the data from the houses as well as the small cell, and do all the necessary processing of that data including applying a QoS scheme. This implies that the small cell-based 'node' needs to be very power efficient, yet be capable of bonding many copper pairs into a single big data pipe and delivering that very high speed Internet access to the paying subscribers who have it today. If there are at least two pairs going to each house from the pedestal/DP, one of the ways to minimise power for the ports serving the wired customers is to utilise a ring architecture.

Essentially only two VDSL2 modems would face the customer premises at the pedestal/DP. There would be a passive cross-connect at the DP so that any household that turned their power off would be switched out of the ring. In a ring architecture, there is always a path to the network, even if one pair is cut to any of the houses in the ring - be it in one direction or the other. If the passive cross-connect is designed properly, those houses served by the ring can also provide power to the DP-based 'node'. This is called back-powering. If it is not possible for whatever reason for enough electrical power to be provided to the 'node' via the network side of the copper at the DP, the combination of back-powering and line-powering would be more than sufficient.

In summary, what have we got?

- Bonded backhaul is essential to maximise available bandwidth to both the wired & wireless consumers. This is a shared pipe that will need QoS for maximum telco revenue.
- Power from the network to the pedestal/DP is essential as emergency communications when the local power fails. Back-powering needs to be an option, as well as mains power where available, so that the whole system runs at peak performance.
- The pedestal/DP 'node' has to be as power efficient as possible while still providing significant bandwidth gains (typically a factor of at least 10x over what is available today) to the wired households served by that pedestal/DP. The best approach for this is a Rings architecture in the case where there are at least two pairs going to each house from the pedestal/DP (this is generally the case throughout much of the developed world).
- This provides a platform for small cell deployments that provides significant amounts of bandwidth, multiple powering options, and proximity to a huge percentage of telco customers.

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The diagrams below illustrate the concept of sharing bandwidth to deliver premium fixed and mobile broadband to the home over the existing copper network.

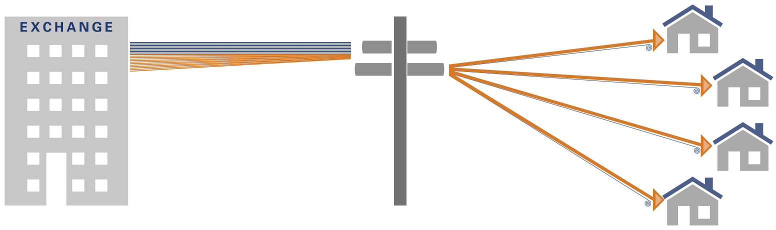

FIGURE 2A shows that not all copper pairs from the home to the distribution point are used and that there is spare capacity in the backhaul network.

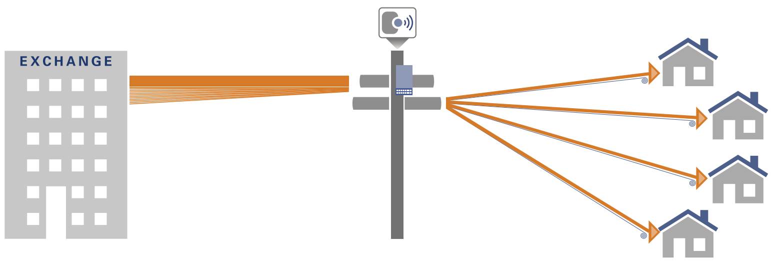

FIGURE 2B shows that the spare copper can be bonded to provide small cell backhaul.

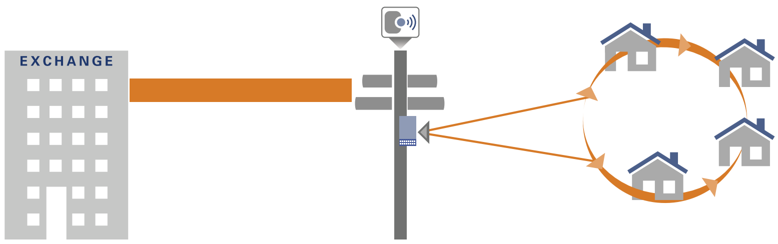

FIGURE 2C shows that by implementing the DSL Rings solution it is possible to share all aggregate bandwidth for the small cell service and fixed broadband to the home enabling maximum possible bandwidth to be delivered to both fixed and mobile users.

Genesis Technical Systems has developed the award wining and patented DSL Rings solution for delivering high speed broadband to the home. For further information about DSL Rings visit the Genesis web site at: **http://www.genesistechsys.com/white-papers** to download the DSL Rings white paper.

References

- DSL Rings white paper (Genesis Technical Systems): **http://www.genesistechsys.com/white-papers**
- 095.03.01 Backhaul for urban small cells (Small Cell Forum)
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About the Author

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With more than 25 years telecom experience, Stephen's specialties include innovation in optical networks and access infrastructure, as well as business models and customer solutions.

Prior to founding Genesis Technical Systems in 2005 Stephen was Vice President of Telecom Services at National Technical Systems, the largest independent testing organisation in the United States. This followed roles that included: Nortel Account Manager for Chatham Technologies, Transmission Engineering Manager at Nortel Networks, Senior Software Test Engineer at Fujitsu and System Design Authority at Bell Northern Research.

Stephen has a B.Eng., from McMaster University in Hamilton, Canada and is co-inventor on the DSL Rings patent, Shared DSL Network and Deployment Method.

About Genesis Technical Systems

Genesis Technical Systems, provider of DSL Rings and mBond, creates cutting-edge broadband technologies that enable fixed and mobile telecoms operators to cost effectively deliver ultra-fast mobile and fixed broadband services, over existing copper networks to meet increasing broadband traffic demands.

DSL Rings® changes the competitive landscape for voice, video and data telecommunications services by enabling superfast Internet bandwidth to rural and urban customers at a fraction of the cost and deployment time of other solutions.

mBond™ provides mobile telecommunications operators with a unique opportunity to dramatically enhance their copper-wired base stations' capacity. Bandwidth needs are significantly increasing with the deployment of high speed data services such as 3G and LTE. Therefore, telecoms operators need to enhance their BTS backhaul as fast as possible while keeping their costs low.

Genesis has offices in Calgary, Canada, and Coventry, United Kingdom.