Technical Paper

Radio access solutions to expand coverage cost-effectively

Alcatel can offer mobile operators new radio access solutions to reduce their total cost of ownership and to allow them to acquire new types of subscriber in fast–growing markets.

In terms of coverage extension, mobile operators need cost-efficient solutions with large coverage and simple backhauling to make new services affordable to geographically more isolated populations. Alcatel's solution is quite simple: low–cost and very compact radio Base Stations, coupled with very high radio performance, allow a 25%+ reduction in Total Cost of Ownership.

For existing mobile coverage, Alcatel's solutions feature a very high capacity BTS and BSC which dramatically reduce the marginal cost of a new subscriber. Extensive use of the half–rate codec is another simple way to increase network capacity at minimal cost, and the simultaneous activation of the Adaptive Multi-Rate codec (AMR) on the Alcatel BTS guarantees an excellent Quality of Service.

ALCATEL

E. Saint–Dizier, E. Le Ho, C. Marzolin

RADIO ACCESS SOLUTIONS TO EXPAND COVERAGE COST–EFFECTIVELY

How service providers can profitably serve new subscribers who currently have no access to telephony.

Huge numbers of people in high–growth economies would like to gain access to mobile telephony. This includes those ready to spend tens of dollars per month to benefit from mobile broadband services, as well as an even higher number of people who would spend less than $5 on calls. The cost of deploying mobile infrastructure (especially the radio access network, which accounts for around two thirds of the total telecom cost and half of the amortization cost) does not generally allow mobile service providers (SPs) to address populations generating such a low ARPU (Average Revenue Per User) with an acceptable pay–back period. By combining a continuous redesign–to–cost strategy with a redesign–to–market approach, Alcatel has developed a set of new radio access solutions to address this type of user.

Each class of population density (dense urban, suburban and rural) requires a specific radio access solution. Alcatel therefore designed solutions that share same goals, i.e. reduce the number of Base Transceiver Station (BTS) sites, and reduce the cost of each BTS. BTS sites represent over 70% of radio access network costs (*Figure 1*), and savings in this area have the biggest impact on total costs.

These solutions contribute to reduce the marginal cost of acquiring new subscribers, and allow mobile SPs to make a profit while serving people who generate an ARPU below $5 per month.

Reduce the number and individual cost of radio sites

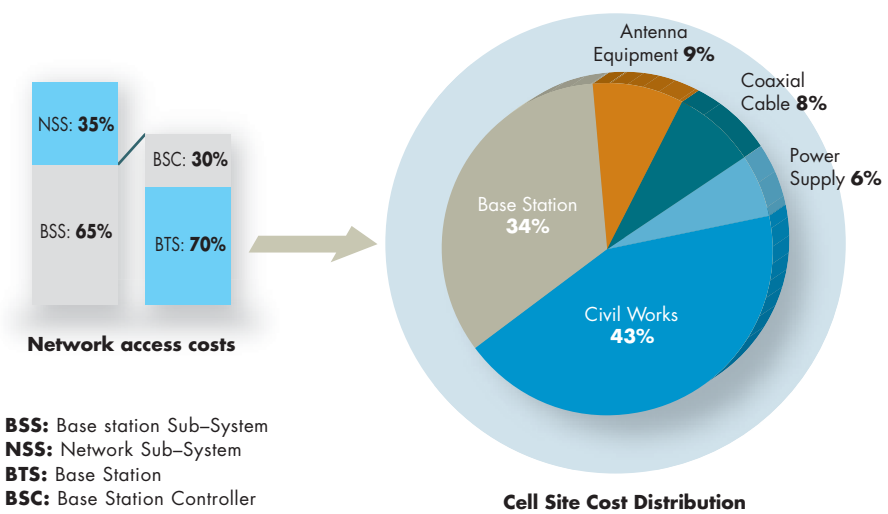
The main elements of the Evolium™ radio portfolio that allow mobile service providers to decrease total cost of ownership (TCO) are:

- A full set of outdoor cabinets, from micro–BTS to multi–standard MBO, more particularly:
  - An ultra–Compact Base station Outdoor (CBO);
  - A medium capacity Multi–standard Base station Outdoor for tropical zones (the Tropical BTS);
- An extremely compact transceiver (TRX) available in all BTS (the Twin TRX module);
- Best–in–class radio performance requiring fewer radio sites;
- A very compact BSC (the BSC Evolution);
- Software algorithms to allow QoS differentiation.

Outdoor BTS enables simple, rapid, cost–effective deployment

In all locations where a building is not available to host indoor cabinets (*Figure 2*), there are many benefits to deploying an outdoor BTS instead of a sheltered indoor BTS. A key advantage is simplified site acquisition: outdoor BTS are much easier to install than a shelter with air conditioning, and the footprint gain may be a major asset, as it multiplies

Figure 1: Base Station sites generally represent more than 70% of radio access network costs

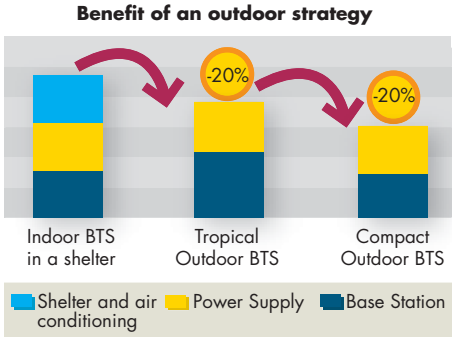


BSS: Base station Sub–System
NSS: Network Sub–System
BTS: Base Station
BSC: Base Station Controller

Figure 2: A typical implementation of an outdoor BTS

the possible locations. Moreover, the possibility of hosting all required equipment in one rack (modules, battery, transmission interface) can reduce the SP's costs by up to 40% (*Figure 3*).

Figure 3: Outdoor BTS leads to greater cost reduction



The ultra- Compact Base station Outdoor (CBO)

The Alcatel CBO Compact BTS is an ultra–compact variant of the widely deployed Alcatel Evolium™ outdoor base station. At under 150 kg, the CBO is extremely easy to deploy, install and commission, in every type of location such as roofs or towers. It exists in several configurations including the typical 3x2 (3 sectors of 2 TRX), perfectly suited to low– and medium–density areas. In addition, its software–centric design enables simple maintenance, best–in–class reliability, and remote upgrade by software download.

Many low–density areas present severe environmental constraints, and can have poor or no transmission infrastructure. The Alcatel CBO is an all–in–one BTS which is compatible with diverse climatic conditions. Components can be easily integrated to enable efficient microwave or satellite backhauling (e.g. Alcatel's 9760 WBS solution, which enables OPEX reduction by drastically decreasing satellite bandwidth costs), as well as solutions for external power supply, such as solar panels.

The tropical BTS: a medium–capacity Outdoor Base Station

The Tropical BTS is an Alcatel Evolium™ outdoor BTS especially adapted to the harsh tropical environment. It is based on the standard outdoor BTS, and uses the same modules. Several optimizations reduce deployment costs, such as the removal of the heater function.

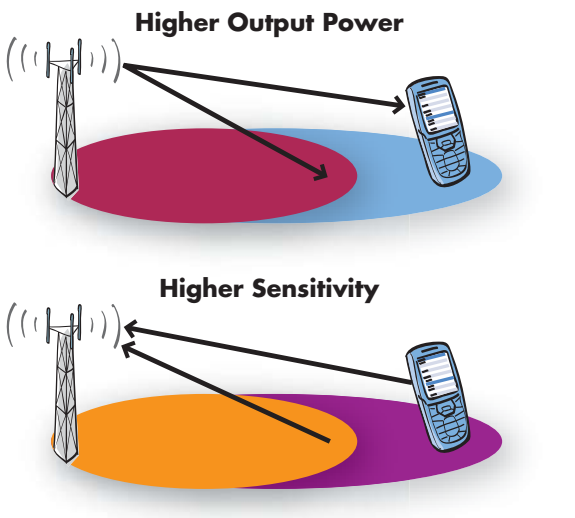
Twin TRX module increases BTS capacity

The Twin TRX is an ultra-compact transceiver module that can be plugged into all Alcatel Evolium™ BTS cabinets (*Figure 4*). This module houses 2 TRX functions in a single box, half the form factor of the previous generation. Thanks to this best-in-class innovation, highly compact configurations are now possible, leading to drastic reductions in site rental costs. As an example, it is now possible to host up to 24 TRX in a single BTS cabinet, which fulfills the needs of operators facing huge mobile subscriber growth in very dense urban areas. In addition, power consumption is significantly reduced (up to 35% in the 1800 MHz band), allowing mobile operators to greatly decrease electricity bills.

Twin TRX module increases radio coverage, decreases number of radio sites

The Twin TRX is not only a breakthrough in terms of housing size: it also brings new functionality. One Twin module can be used as a "super" TRX, by combining the two embedded TRX functions to provide more than twice the radio performance of a regular TRX, in both downlink (BTS to handset) and uplink (handset to BTS). This significantly reduces the number of radio sites needed to obtain same–quality coverage over a given area – by up to 30% in rural zones.

Figure 5: The Twin TRX increases downlink/uplink radio coverage

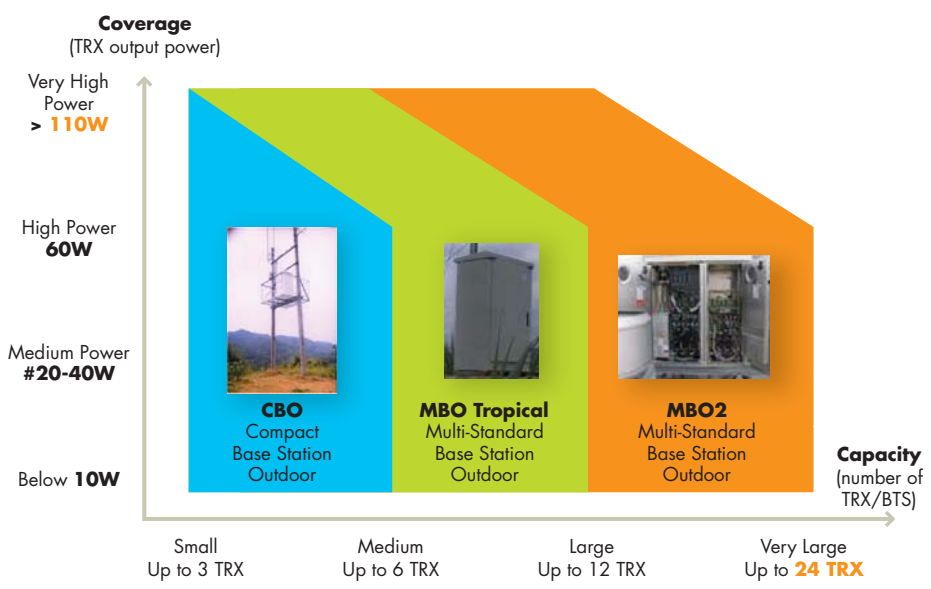


This improvement in radio performance (*Figure 5*) comes from the use of transmit diversity (2Tx diversity: see insert) to increase the downlink budget, and the use of receiver diversity over four receivers (4 Rx Diversity: see insert) to increase the uplink budget.

As an example, the use of 2Tx Diversity allows the transmitter to reach an equivalent output power of over 110 W, while a regular medium–power TRX delivers 45 W.

The Twin TRX can be efficiently associated with an extended cell feature, which allows SPs to overcome the theoretical maximum coverage of a BTS specified in the 3GPP standard (35 km). Special algorithms allow an SP to double this.

Figure 4: Twin TRX embedded in all BTS



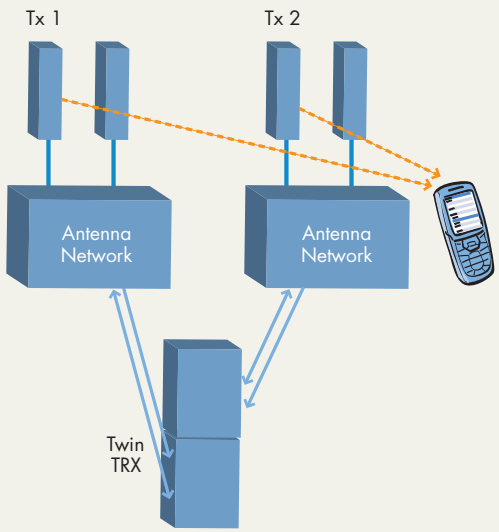
Transmit Diversity (2 Tx Diversity)

The two branches of the Twin TRX module send the same TRX signal to two different antennas, yielding an on–air combining gain of 3dB. To ensure de–correlated propagation, both signals are sent with a short time delay in between. This leads to an additional diversity gain of up to 3dB. TX Diversity works with all types of mobile stations since it is fully transparent to the receiver, which can already handle multiple paths with different arrival times. The total resulting gain is environment–dependent, since it is closely linked to the level of de–correlation between paths. It varies from 4dB in rural environments to up to 6dB in dense urban environments. Consequently, the equivalent TRX output power is very high, i.e. more than 110 Watts even in low–density areas, which dramatically improves coverage.

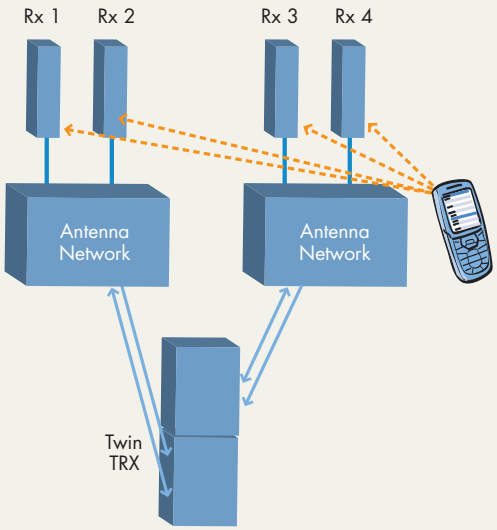
4 Receive Diversity (4Rx Div)

The principle of 4Rx diversity is to receive the uplink signal on four different antennas, taking advantage of the two branches of the Twin TRX. Going from two to four receive paths results firstly in an increase in the Signal to Noise Ratio (SNR) gain. Indeed, doubling the number of antennas leads to more signal power received at the BTS, and an additional diversity gain. Secondly, the interference margin can be further reduced thanks to improved interference cancellation. As for Transmit Diversity, the final resulting gain is environment–dependent. Compared to a no–diversity reception, it varies from 6.4dB in rural environments to up to 10dB in dense urban environments (–117dBm equivalent Rx sensitivity). Thus, 4Rx diversity improves the uplink, thereby widening coverage.

Downlink: Tx Div



Uplink: 4Rx Div



Addressing more subscribers by quality differentiation

When a mobile SP makes best use of its radio infrastructure, it also reduces the marginal acquisition cost of new subscribers. This is particularly true in dense urban areas, where mobile penetration is already very high, and where the remaining unaddressed population has limited disposable income, likely to yield a very low ARPU. The target is therefore to increase network capacity to absorb this new population of entry–level subscribers, by deploying the minimum equipment needed to avoid traffic congestion. It is possible to achieve these two goals through a series of features that maximize the efficiency of each TRX deployed, to address more subscribers with quality of service differentiation.

An important efficiency improvement can be achieved with an extensive use of Half Rate, thanks to several features that enable good voice quality, such as AMR (Adaptive Multi–Rate codec: see insert) and TFO (Tandem Free Operation: see insert). Priority mechanisms enable the assignment of entry–level subscribers to half rate, and high–traffic users to full rate. Other features, such as Preemption and queuing with priority, further differentiate quality of service among users. This enables each TRX to handle more entry–level subscribers while maintaining the same quality of service to high–traffic subscribers.

Combining Half Rate (HR), AMR and TFO

The introduction of dual–rate mode allows new users to be served in HR mode beyond a customizable load threshold. This provides considerable capacity gains by multiplexing two users on the same time slot during traffic peaks. The gain depends on the penetration of dual–rate mobiles and the number of dual–rate TRX in the cell; the HR flexibility feature makes it possible to define the dual–rate capability for each TRX. For example, for a 50% penetration rate of dual–rate mobiles, the capacity of a cell with four TRX, two of which are dual–rate capable, is increased by 30%. However, a mobile subscriber in HR mode may suffer from poor speech quality in bad radio conditions or in tandeming (mobile–to–mobile calls).

The use of AMR (Adaptive Multi–Rate codec) mitigates the quality issues of dual–rate. Indeed, AMR Half Rate provides better speech quality than the ordinary HR codec, and is as good as the full–rate codec. Thus, limiting use of dual–rate mode to AMR–capable mobiles leads to a considerable capacity gain, while preserving end–user quality of service.

If dual–rate mode is also enabled for non–AMR capable mobiles, the TFO (Tandem–Free Operation) feature can be activated to reduce the impact of the HR codec. Here, the transcoders are bypassed in the case of mobile–to–mobile calls. This yields much better speech quality, since there is no need for a double transcoding.

BSC Evolution absorbs fast traffic growth in dense urban areas

The base station controller (BSC) is one of the key elements of a mobile network. It controls handover, frequency use and signal power for every mobile user. As the mobile subscriber base grows, the capacity of the BSCs and their associated floor space in crowded cities of high–growth economies can rapidly become an issue. Alcatel's answer is the high–capacity, small–volume BSC, an evolution of the standard Alcatel Evolium™ BSC. The BSC Evolution (*Figure 6*) has the capacity to manage up to 2,000 TRX per cabinet, allowing SPs to connect more cells per BSC, thereby optimizing network investments with a more centralized architecture.

Figure 6: The BSC Evolution

Alcatel thus surpasses other equipment vendors: BSC Evolution is based on the IT industry ATCA standard. This allows the use of standard units, leading to reduced manufacturing costs and faster time to market.

Serving new market segments profitably: concrete examples

All the above solutions help SPs to serve new market segments without breaking the bank. By decreasing the cost of each radio access site, Alcatel helps reduce the marginal cost of acquiring a new subscriber, whatever his environment. The following analysis shows by how much the expenses linked to the Radio Access Network (RAN) can be reduced using these new solutions.

Network extension to remote, rural areas

Hypothesis

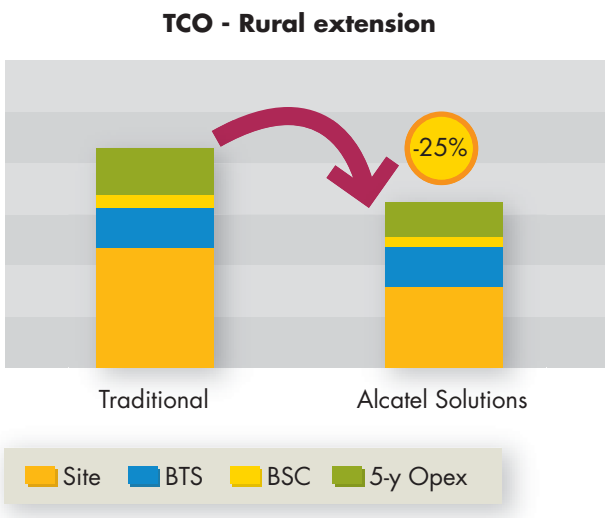
An SP wants to extend its GSM coverage in a rural area with low population density. The business case shows that traditional radio access technology would lead to costs disproportionate to expected revenues.

In this study, we evaluated the cost decrease that Alcatel solutions could bring, through extensive use of several types of outdoor BTS and Twin TRX with very high radio performance (transmit and receive diversity). All sites have 60 m towers as well as microwave backhaul links.

Results

The usage of very high radio performance TRX decreases the number of sites needed to cover these rural areas by 30%, leading to a direct CAPEX reduction of nearly 25%. Operational expenses are also reduced by 30% due to reduced site rental, energy and maintenance costs. Our calculations indicate a 25% lower TCO for the radio access solution over five years (*Figure 7*). Thanks to Alcatel's radio solutions, new coverage areas can be exploited, while keeping revenues above the break–even threshold.

Figure 7: 25% reduction in TCO over five years by deploying Alcatel solutions in rural areas



Serving more customers in existing dense urban coverage areas

Hypothesis

An SP serves 60–80% of the total estimated addressable market of a dense urban area, but sees its customer acquisition rate leveling, because of a budget barrier in its entry offer. Attracting new subscribers can be achieved through aggressive pricing (potentially using a new, budget brand), but significant network capacity extension is required to cope with the traffic increase without degrading the quality of service for existing subscribers. As the new users will likely generate a lower ARPU, the launch by the SP of an entry–level package is only possible if the incremental investment is low enough.

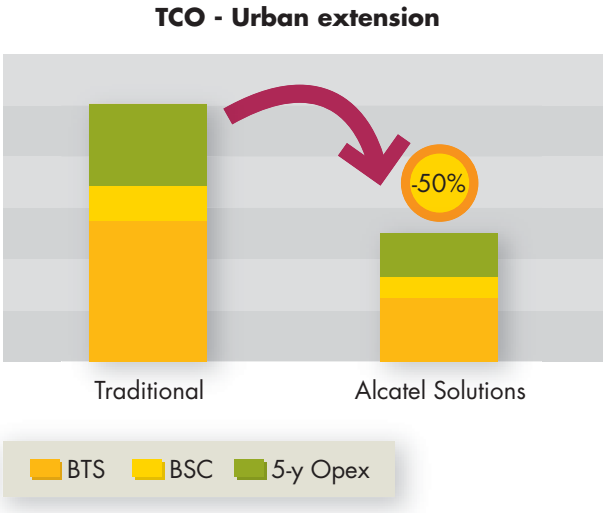
We assumed that the SP's target is to increase its subscriber base by 25%, using large–capacity BTS and BSC to decrease costs compared to traditional solutions. In addition, we simulated a significant activation of half–rate for all AMR–capable terminals, and reasonably assumed 15% AMR penetration for existing subscribers, and 40% for new subscribers, relying on the AMR support built in to the Ultra–Low Cost GSM handsets now entering the market.

Results

In both cases the capacity extension requires no additional sites. In the traditional case, 70% of sites would need upgrades, with an increase of 17% in the number of TRX leading to the deployment of extra cabinets and increased site rental fees. With the Alcatel solutions, only 38% of sites would need upgrades, and only 9% additional TRX would need to be deployed. Thanks to the very compact Twin TRX, no new cabinet is necessary. The additional CAPEX needed for the extension is 51% lower in this case. Overall operational expenditure is also reduced by 50%: deploying fewer TRX and cabinets reduces expenses related to site rental, energy, maintenance and leased lines. Finally, the total cost of ownership over five years decreases by

50% (*Figure 8*). This dramatic reduction in the marginal cost of acquiring new subscribers allows this SP to deploy enough capacity for new subscribers, without degrading quality of service, while maintaining a profitable business.

Figure 8: 50% less additional TC0 over five years by deploying Alcatel solutions in dense urban areas



Conclusion

Alcatel's new radio access solutions reduce total cost of ownership and allow subscriber base expansion in fast–growing markets. As the new subscribers may have very different geographical and revenue–generating characteristics, SPs will have to choose the most appropriate radio access solution according to their strategic goals.

However, whatever the scenario, Alcatel can propose solutions that ensure the lowest possible marginal cost for acquiring new subscribers.

These radio access solutions now allow mobile SPs to create a profitable business by providing mobile telephony access to very low ARPU subscribers. This is a unique opportunity for SPs to ensure future growth. As traffic is subsequently expected to dramatically increase, they will also need to ensure that the cost of their transport infrastructure follows the same TCO optimization trend.

Alcatel strongly believes that a network transformation towards IP, ultimately reaching the BTS level, is the best answer to decrease the cost per transported bit.

Emmanuel Saint–Dizier
is Product Marketing & Business Support manager for the Alcatel Mobile Radio Division, located in Kuala Lumpur, Malaysia.
Emmanuel.Saint–Dizier@alcatel.com.my.

Erwan Le Ho
is a Radio Network Design Expert in Alcatel's Mobile Radio Division, located in Vélizy, France.
Erwan.Le_Ho@alcatel.fr

Christian Marzolin
is Business Consulting Manager in Alcatel's Mobile Communications Group, located in Vélizy, France.
Christian.Marzolin@alcatel.fr.

Glossary

AMR Adaptive Multi-Rate codec
ARPU Average Revenue Per User
BSC Base Station Controller
BTS Base Station
CAPEX Capital Expenditure
CBO Compact Multi-Standard Base Station Outdoor
EBITDA Earning Before Income Tax, Depreciation and Amortization
EDGE Enhanced Data rates for GSM Evolution
E-GSM Extended-GSM band
GDP Gross Domestic Product
GPRS General Packet Radio Service
MBO Multi-Standard Base Station Outdoor
MBS Multi-Standard Base Station
OPEX Operational Expenditure
QoS Quality of Service
RAN Radio Access Network
SNR Signal to Noise Ratio
TCO Total Cost of Ownership
TFO Tandem Free Operation
TRX Transceiver

ALCATEL