STRATEGIC WHITE PAPER

# Converged Mobile Backhaul

## Using microwave packet radio for mobile backhaul in a High Leverage Network™ architecture

Microwave packet radio technology has a key role to play in mobile backhaul when transforming to a High Leverage Network™ architecture. It is a technology which keeps the transformation cost curve as flat and as short as possible. This paper demonstrates why microwave packet radio is the most economical choice for self-built backhaul and identifies why it is also the strategic choice among microwave alternatives.

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# 1. The benefits of microwave packet radio in a converged mobile backhauling

This section deals with the process of shaping the backhauling network to service the existing, revenue-generating mobile services and to be ready to fully support the next-generation of mobile services, in particular Long Term Evolution (LTE).

The process of driving the evolution of a backhaul network to a target architecture without service disruption and at a lower cost is based on choosing the right strategy. This section describes how microwave packet radio fits in this transformation strategy and the many benefits it provides in a converged mobile backhauling.

## 1.1 Role for a value-added, innovative microwave packet radio technology

As service providers strive to leverage their network assets to deliver a compelling array of innovative business, mobile and residential services to their customers, the optimization of their transport infrastructure plays a key role in ensuring profitability and a superior user experience.

The High Leverage Network (HLN) architecture addresses the key challenge of simultaneously providing operators with innovative, revenue-generating, value-added services and efficient low-cost transport, assuring the highest Quality of Experience (QoE) to the end customers.

Microwave packet radio is key in a converged mobile backhauling, fulfilling the above requirements and facing a major transition from plain, TDM-based services to data, packet-based services. Microwave packet radio is unique in supporting operators' needs to drive the technical transformation while preserving a low total cost of ownership (TCO) because it is:

- *Packet based* – Open to future transformation (e.g., the all-IP model pursued by LTE) to provide Future Mode of Operation (FMO)
- *Backward compatible* – Supports existing mobile services (2G/3G PDH/SDH installed base) to provide Present Mode of Operation (PMO) to ensure they are ready to move to packet through a software upgrade
- *Service aware* – Customers' QoE is in line with their real service profile
- *Deterministic* – Customers' satisfaction is not related to the status of the network
- *End-to-end* – A unified MPLS-based networking runs from access to core, enabling the transport of services through Pseudowire (PWE3) technology through simple provisioning

## 1.2 Drastic reduction of backhauling cost

The key characteristics of microwave packet radio enable the TCO reduction of the backhauling network. Four main cost reduction areas can be addressed in a transition of backhauling to full packet:

- Reduce the cost of running a large variety of elements that are part of the network inventory and require validation
- Reduce the capital cost associated with a high number of elements within the backhauling
- Reduce the operations cost through a single, end-to-end, fully automated service manager
- Stop investment in legacy technologies and gradually allow their removal while introducing the packet switched radio elements

*Fewer Network Elements To Manage And A Single End-To-End Way Of Operating The Convergent Network Create The Condition For The Lowest Total Cost Of Ownership.*

*Flexible, Non-disruptive Evolution From Current PDH/SDH Radio Network To The Converged Packet Network Allows Positive Cash Flow For The End-To-End Business Model And Removes Risk.*

## 1.3 The strategic decision driving the transformation

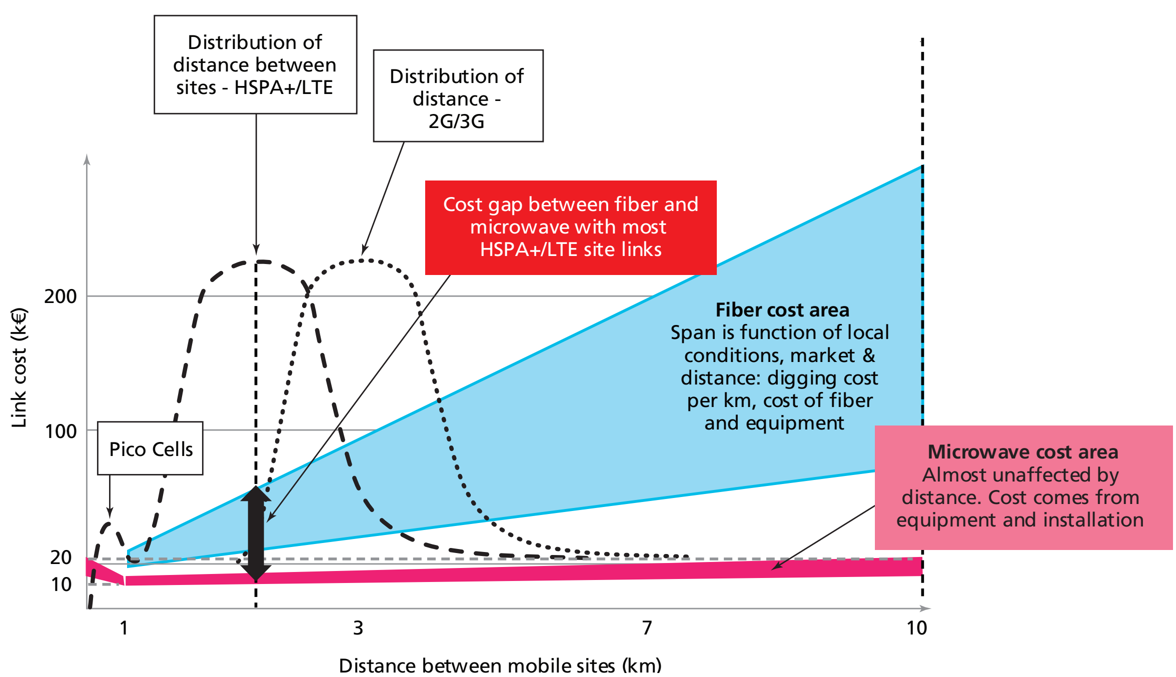
Present mobile backhauling networks are based on three main technologies (microwave, fiber and copper). Microwave accounts for approximately 60% of the total, but it is important to note that when microwave is used by one operator, it is normally used for more than the 80% of the sites in the network.

A large sized radio access network (RAN) can include up to 20,000 sites. Any new service introduced into the network can impact the existing backhauling technology; in the case of microwave, this can affect approximately 16,000 sites. Therefore, the choice of the next generation backhauling model is strategic.

In general, copper is not perceived as a strategic option due to its intrinsic limitations. Microwave was initially thought to be inadequate to serve next generation networks, with fiber seen as the only solution. Microwave packet radio used in a converged backhauling makes it clear that microwave remains the most economical choice for self-built backhauling.

This paper demonstrates why microwave is the most economical choice and identifies the strategic choice among microwave alternatives. Figure 1 suggests that a gap exists between microwave and fiber even for the next generation of small antennas that were introduced to increase the coverage and employ higher frequencies suitable for urban environments.

**Figure 1. Comparison of cost link between fiber and microwave**

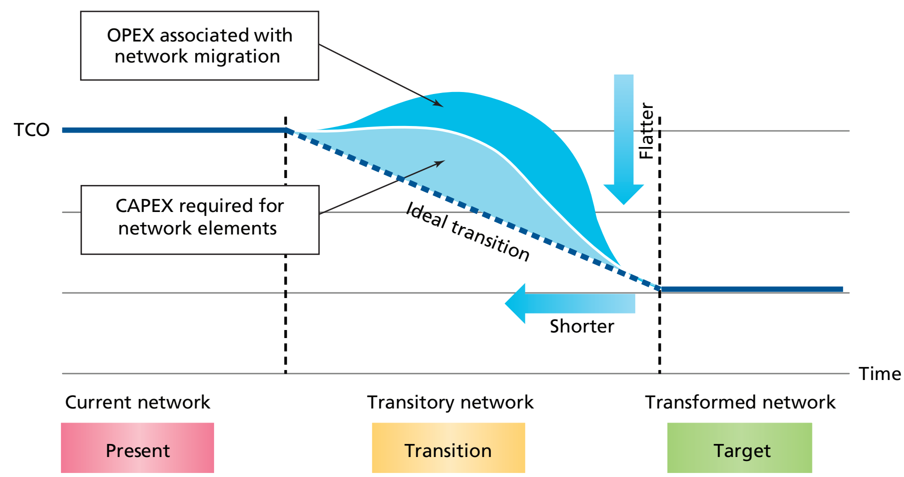



The increased density of cells impacted over the backhauling derived from the evolution of mobile services to HSPA+ and LTE. The move toward next-generation mobile services comprises steps that are often referred to as compelling events[1]. These steps identify upcoming events in the backhauling and the necessary actions required. During the transformation of their network, operators can modify the TCO associated with their assets.

[1] A compelling event is an event that happens at a determined point in time (i.e., new service launch, new technology deployed) impacting the network. The effect of the event is compelling because it forces a change into the current network structure with an accompanying cost to cope with the transformation.

Figure 2 provides a qualitative representation of how TCO changes after a well studied and implemented network transformation — a transformation with a goal of keeping the temporary cost increase due to extra CAPEX and OPEX as flat as possible and as shortest as possible before reaching the target scenario at a lower TCO.

**Figure 2. Transforming the network to reach a lower TCO**




In the path toward LTE there are three compelling events that have important effects on the current mobile backhauling infrastructure:

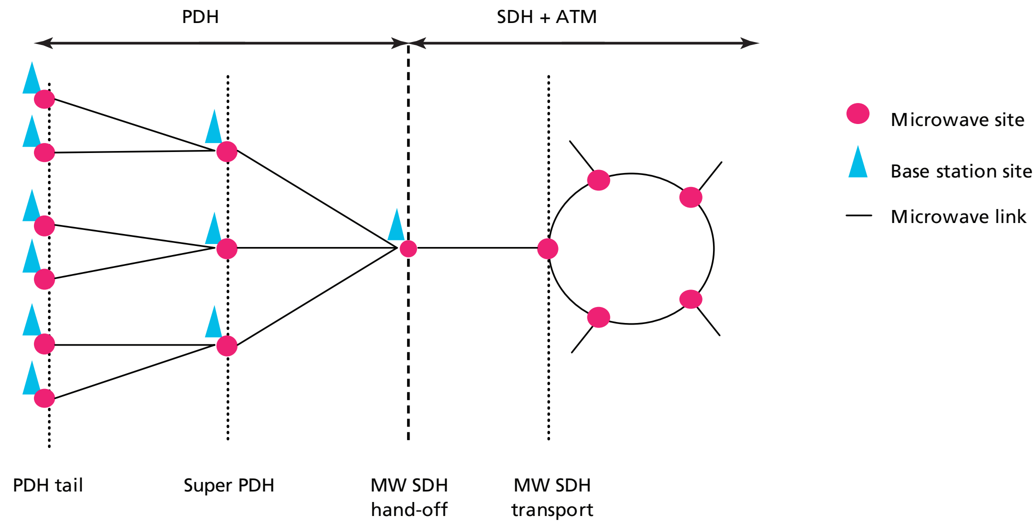
- *HSDPA mass adoption* – The number of ATM E1/T1s assigned to data services increases, together with the bandwidth requested on microwave links that connect base stations to microwave backhauling hubs.
- *HSPA+ and initial LTE deployment* – Ethernet becomes the only technology used for backhauling, with a further increase of bandwidth demand on microwave radio links.
- *Convergence* – A unified backhauling is employed to carry mobile and fixed services.

The choice of the best microwave technology to cope with these compelling events becomes strategic in transforming the existing wireless backhauling network.

## 1.4 Considerations in the decision to transform the network

Service providers must have an awareness of the commonly adopted model for microwave backhauling. Base stations are connected to microwave through a small number of T1/E1 PDHs. As shown in Figure 3, in the PDH domain there is no aggregation, and the typical PDH installed capacity is ≤ 4/8 T1/E1s for tails, 16/32 for super PDHs, and 63 for SDH hand-off. Aggregation is done at the ATM/SDH layer for 3G.

Figure 3. Representation of a current mobile backhauling network




In addition, the service provider must be aware of the number of network elements affected by the transformation and the long-term limitations of the current capabilities. Table 1 provides a representative view of the network elements in a large sized RAN (Alcatel-Lucent assumption based on operators in EMEA). The percentage of microwave sites compared to the total number of sites illustrates the impact of changes over the backhauling network.

Table 1. Microwave sites in a large RAN (EMEA case)

| ITEM | PERCENTAGE | QUANTITY |
|---|---|---|
| RAN sites (large RAN) | 100% | 20,000 |
| Percentage of sites connected to microwave | 80% | 16,000 |
| Percentage of PDH tails | > 60% | 9,600 |
| Percentage of super PDH | approx 25% | 4,000 |
| Percentage of SDH hand-off | < 15% | 2,400 |

Finally, the service provider must analyze the characteristics of the desired target network. The final network aims to support 4G and convergent services (i.e., LTE, 802.16m) not only from a technical standpoint, but to fulfill the following TCO requirements:

- Reduce the CAPEX associated with a high number of elements within the backhauling network as well as stop investing in legacy technology
- Reduce the operating cost of handling and validating too many different families of network elements, as well as simplify the management and provisioning activity

## 1.5 Transformation models and expected results

Backhauling is a fundamental component of the aggregation network. A change or upgrade in the customer-facing access devices (i.e., base stations for mobile) can have a big impact in the backhauling as well.

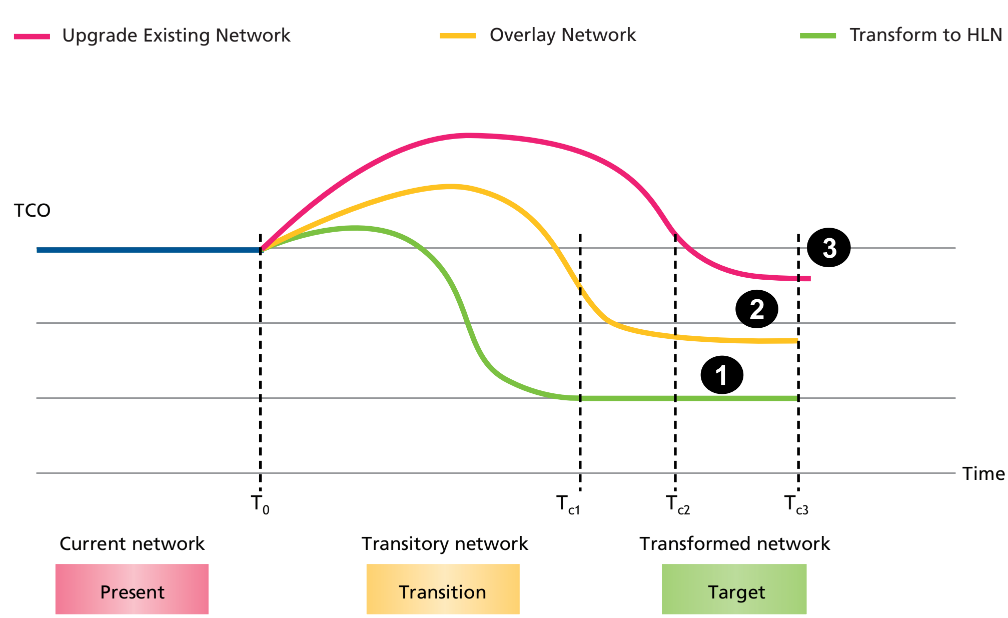
Several strategies to tackle the transformation of backhauling networks can be adopted; this paper considers three main approaches as shown in Table 2.

**Table 2. Strategies to transform backhauling networks**

| STRATEGY | TRANSFORM TO HLN ❶ | OVERLAY NETWORK ❷ | UPGRADE EXISTING NETWORK ❸ |
|---|---|---|---|
| Approach | Transformation to packet radio technology | Use plain IP overlay | Upgrade existing (legacy) technology |
| Value | Upgrade/replace microwave to packet radio when needed<br>Invest money on new integrated packet radio technology<br>Converged backhaul | Maintain existing microwave<br>Invest money on IP equipment<br>Co-existence of two layers: Not a converged or integrated solution | Upgrade/replace microwave capacity when needed<br>Keep investing in hybrid technology<br>Not strategic |
| Outcome | Enable converged packet transport for IP services and legacy services | Full IP functionality achieved, but increased equipment in backhaul with extra OPEX.<br>Increased management complexity | Cannot move to full IP functionality: Packet is just Ethernet, TDM cannot converge to packet, ATM is treated as TDM traffic. |
| Microwave solution type | Packet nodal radio: Integrated solution, providing multi-service aggregation, networking, and transmission. All traffic is transported over a converged layer optimized for air bandwidth, scalable in capacity and nodal directions transmission. | Cell Site Aggregator (CSA) + point-to-point microwave: Solution based on two devices, not integrated. CSA handles service aggregation and networking tasks, while microwave handles the point-to-point transmission. All traffic is converted into Ethernet frames. | Two options are possible:<br>Option A: Hybrid point-to-point: TDM and Ethernet traffic is overlaid and handled by two different internal switches within the microwave product. Handles one point-to-point radio direction at a time.<br>Option B: Hybrid nodal: TDM and Ethernet traffic is overlaid and handled by two different internal switches within the microwave product. It can also provide nodal configuration with limitations in directions and scalability imposed by the dual switch architecture. |

As a result of the transformation, TCO is expected to follow one of the qualitative curves shown in Figure 4 where the mapping between strategies and the expected result is also shown.

**Figure 4. TCO curves and applicable strategies for the transformation**



## 2. Quantifying the benefit of a strategy

This section discusses the impact on backhauling and how TCO is influenced when the network backhaul transformation strategies are implemented. Strategies are compared in terms of the following three steps or compelling events:

- *Compelling event # 1, HSDPA mass adoption* – Mobile data services demand for more capacity requires that extra ATM E1/T1s or Ethernet links are needed per base station. The bandwidth requested between hub points increases, requiring an upgrade of capacity. There is a strong impact on the aggregation links, because the current capacity is often dimensioned to a static carrying of the voice services separated by the data services with no means of introducing a statistical multiplexing.
- *Compelling event #2, HSPA+ and initial LTE deployment* – Base stations are forced to migrate to Ethernet connectivity which means there is no longer support of native TDM. This event is more disruptive than event #1 because it forces a change in the technology used for the backhauling connectivity. Here operators cope with the introduction of evolved mobile services such as HSPA+ and LTE that require an entirely Ethernet-based connectivity. TDM is no longer carried as a native service and legacy technology, such as PDH and ATM, must be removed. Bandwidth increases in every sector of backhauling, not just in the aggregation. Links from tail to hub points can exceed 45-50 Mb/s.
- *Compelling event #3, Convergence* – The resulting network can be considered as an integrated, end-to-end operated network, where the provisioning of services is enabled across a unified network infrastructure. As a final result in the transformation step, the backhauling network should support the convergence of fixed and mobile services.

Table 3 summarizes the overall effectiveness of each strategy compared against the transformation to HLN architecture, used as a reference. Each strategy is measured through five parameters associated with the evolution of a backhauling network and the reduction of its TCO.

The number of black stars associated to a parameter visually shows the obtainable improvement for that specific item relative to HLN. Values range from no stars (meaning no improvement at all) to five stars (meaning a great benefit due to the effectiveness of the strategy considered).

**Table 3. Comparison of backhaul transformation strategies**

| | | STRATEGY | | | |
|---|---|---|---|---|---|
| SCOPE | | TRANSFORM TO HLN (1) | OVERLAY NETWORK (2) | UPGRADE EXISTING NETWORK – OPTION A (3) | UPGRADE EXISTING NETWORK – OPTION B (3) |
| Inventory | Reduce the number of product families/types in the network | ★★★★★ | ★★★⯪☆ | ☆☆☆☆☆ | ★★★⯪☆ |
| NE reduction | Reduce the total number of network elements in the network | ★★★★★ | ★★★⯪☆ | ☆☆☆☆☆ | ★★★⯪☆ |
| Site intervention | Reduce the need of people activity into a site | ★★★★★ | ★★★⯪☆ | ☆☆☆☆☆ | ★★★★⯪ |
| Operation | Reduce the overall management and provisioning complexity | ★★★★★ | ★★★★☆ | ☆☆☆☆☆ | ★★★☆☆ |
| Openness to future | Readiness to the introduction of new features, technologies | ★★★★★ | ★★★★★ | ☆☆☆☆☆ | ★★☆☆☆ |

If Table 3 is meant to give a reference of how much a strategy is able to get close to the "transformation to HLN", next sections will detail what happens to the backhauling network as a consequence of choosing a specific strategy. Next tables will use different symbols: a + indicates that parameter if positively affected by a chosen strategy (and increases the strategy's effectiveness), a − indicates a decrease and a = indicates is neutral.

Values are cumulate, and are tied to the TCO computation as shown in the last section of this paper.

## 2.1 Strategy 3, Option A: Upgrade existing network, extending the ATM infrastructure

This strategy extends the life of the existing ATM RAN and leverages on the installed backhaul solution (stop gap solution). It is cost effective in the short term, but these investments will be lost when Ethernet is introduced in the RAN to launch new services in 3G or migrate to LTE. Further evolution is not applicable for this strategy. In this case the transformation cost after the three compelling events occur is greater than 70% of the reference value (see Strategy 3, option B).

This strategy's impact on the TCO is described in Table 4.

**Table 4. Effectiveness of the Upgrade strategy – Option A**

| COMPELLING EVENT | INVENTORY | NE REDUCTION | SITE INTERVENTION | OPERATION | OPENNESS TO FUTURE |
|---|---|---|---|---|---|
| HSDPA mass adoption | = | = | - | - | -- |
| | ATM upgrade affects existing devices | See previous | Installation and Commissioning (I&C) in all hubs and hand-offs | Impact on management & provisioning, little training | Suitable for PMO, not for FMO |
| HSPA+ and initial LTE deployment | -- | -- | -- | -- | -- |
| | Not applicable. Must migrate to another solution. | | | | |
| Convergence | -- | -- | -- | -- | -- |
| | Not applicable. Must migrate to another solution. | | | | |

Although this strategy is a good tactic for the HSDPA problem, no evolution is supported. This strategy starts following the curve #3 in Figure 4, but soon risks diverging. Compelling event #2 forces a technology shift to another strategy. Moreover, no convergence is possible through this strategy.

## 2.2 Strategy 3, Option B: Upgrade existing network using Ethernet capabilities of hybrid platforms

This strategy anticipates the technology move to Ethernet, yet maintains the current hybrid backhauling structure. This strategy copes with the widespread adoption of Ethernet. However, capacity and IP functionality must be addressed, which means extra CAPEX at every step. The transformation cost after the three compelling events is used as the reference value for the impact assessment. This strategy's impact on the TCO is described in the Table 5.

**Table 5. Effectiveness of the Upgrade strategy – Option B**

| COMPELLING EVENT | INVENTORY | NE REDUCTION | SITE INTERVENTION | OPERATION | OPENNESS TO FUTURE |
|---|---|---|---|---|---|
| HSDPA mass adoption | = | - | -- | = | = |
| | Ethernet microwave is replaced, new switches in rings. Inventory is increased. | Slight increase in NEs | I&C in all the network sites | Impact on management & provisioning, little training | Open with limits. DDF needed in hubs, with one microwave per PDH direction and one hybrid nodal. TDM and Ethernet still overlayed on radio. |
| HSPA+ and initial LTE deployment | = | - | + | + | = |
| | No change | No variation | Upgrade on links only | Ethernet end-to-end OAM | Open, however TDM subsystems are no longer usable and there is poor Ethernet scalability |
| Convergence | = | - | + | + | = |
| | No change | No variation | Capacity upgrade on links only, often corresponding to a change of profile | Ethernet end-to-end OAM | Leverages on previous compelling event but same limits are still present |

This strategy corresponds to curve #3 in Figure 4. The transformation is possible and a lower TCO can be accomplished, but with a risk of having the break-even point at a point in time Tc3 >> Tc1. In this scenario, networks remain distinct and the only convergence is technical due to the wide-spread usage of Ethernet.

## 2.3 Strategy 2: Overlay network

This strategy introduces IP connectivity to the existing network by overlaying new technology. Operation suffers due to the lack of integration which increases costs due to maintaining and operating two networks. Scalability and evolution for the microwave layer also become more complex and costly to handle and plan.

In this strategy the transformation cost after the three compelling events is less than 15% of the reference value (see Strategy 3, option B).

This strategy's impact on the TCO is described in Table 6.

**Table 6. Effectiveness of the Overlay strategy**

| COMPELLING EVENT | INVENTORY | NE REDUCTION | SITE INTERVENTION | OPERATION | OPENNESS TO FUTURE |
|---|---|---|---|---|---|
| HSDPA mass adoption | - | -- | - | - | + |
| | CSA family introduced which causes an increase in inventory | No NE reduction due to CSA deployment | I&C in hubs, hand-offs | Impact on operation, people training, different management and provisioning | Open, but complex hub node: 1 point-to-point microwave per radio direction + 1 CSA + 1 radio uplink. A large CSA as front-end for service node is requested. |
| HSPA+ and initial LTE deployment | + | + | - | + | ++ |
| | ATM removed | ATM is removed in front of service nodes, slight reduction | I&C in tail sites | End-to-end IP OAM achieved, but still different management and provisioning | Open, IP/Ethernet fully supported end-to-end |
| Convergence | + | + | = | + | ++ |
| | No variation | No change | Upgrade on microwave links which often means replacing the radio component | End-to-end IP OAM achieved, still different management and provisioning | As above |

With this strategy, IP is available with no change in microwave but it requires operation of two networks because management is not integrated. Overlay is still the limiting factor although it guarantees full IP. This strategy corresponds to curve #2 in Figure 4.

Convergence is realized at a logical layer due to the enablement of IP from access to aggregation, but networks remain different (overlay).

## 2.4 Strategy 1: Transform to HLN

Leveraging on integrated packet radio backhaul addresses the current requirements for every step (ATM optimization for 3G, capacity growth for HSPA+), while allowing full migration of all traffic to converged packet transport when HSPA+ and/or LTE are launched. No extra devices are introduced, providing an integrated solution and single network to operate. This solution provides the lowest TCO available.

In this case the transformation cost after the three compelling events is less than 30% of the reference value (see Strategy 3, Option B).

This strategy's impacts on the TCO are described in Table 7.

**Table 7. Effectiveness of the Transform to HLN strategy**

| COMPELLING EVENT | INVENTORY | NE REDUCTION | SITE INTERVENTION | OPERATION | OPENNESS TO FUTURE |
|---|---|---|---|---|---|
| HSDPA mass adoption | = | + | - | = | + |
| | Upgrade of existing nodes, no change | Nodal devices enable the reduction of point-to-point PDH | I&C hubs, hand-offs | ATM to manage, little people training | Work in PMO, ready to move to FMO |
| HSPA+ and initial LTE deployment | + | + | - | + | ++ |
| | No longer PDH microwave, only one family of microwave packet radio devices | No variation | I&C in tail sites | End-to-end service and Ethernet OAM | Open, IP/Ethernet fully supported end-to-end |
| Convergence | + | + | + | ++ | ++ |
| | No change | No variation | Capacity upgrade on links only, meaning a simple profile change | Integrated, end-to-end service and Ethernet OAM | As above |

With this strategy, microwave is not changed as the solution is integrated and packet functions can be enabled on demand, with nodal capability embedded. This strategy corresponds to curve #1 in Figure 4. The main advantage is that a unique convergent layer is realized, independent from the technology employed. End-to-end management and provisioning let operators control their network in an integrated way.

A converged backhauling network can be used to carry fixed and mobile services, as well as business and residential. An example of convergence is the densification of ADSL/VDSL cabinets to cope with increased capacity to service multimedia applications such as HDTV.

An off-net VDSL cabinet can be deployed by a mobile site and connected to the existing microwave backhaul network to reach the central office.

## 3. Conclusion

Microwave packet radio is a strategic choice for backhauling transformation. The target of the transformation is a full packet-based, unified network where backhauling delivers any services over microwave or fiber to fixed or mobile devices.

*Evolve The Network To A Single, Integrated Packet Based Paradigm.*

Combining the parameters associated with the transformation of the backhauling results in the graph shown in Figure 5, which illustrates the overall cost related to each strategy.

**Figure 5. Backhaul transformation costs**

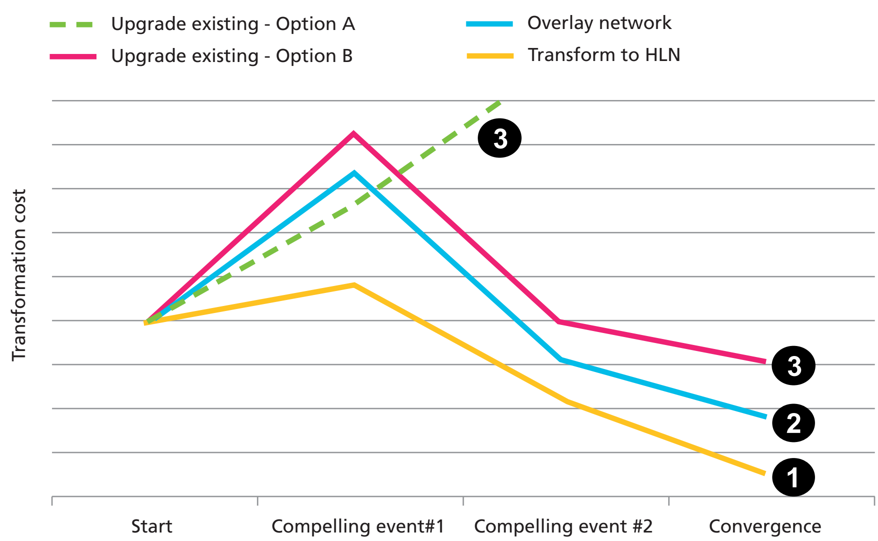



Figure 5 shows how the expected results depicted in Figure 2 are confirmed. At the heart of the strategy to transform to an HLN architecture is the microwave packet radio technology — a technology which is key in coping with the two requirements of keeping the transformation curve as flat and as short as possible. The final economical figure cannot be matched by any other strategies.

Part of the Alcatel-Lucent microwave products portfolio, 9500 Microwave Packet Radio (MPR) is the technical enabler for the transformation of the mobile wireless backhauling to an HLN architecture. Through a software upgrade, MPR can evolve from the PMO, where it supports a mix of TDM-based and Ethernet-based services suitable for 2G and 3G services, to an FMO, where all traffic is ported to Ethernet and services are segregated by means of MPLS pseudowires.

The radio characteristics of MPR also support the requirements outlined at the beginning of this paper, and offer deterministic performance to the low latency services while enabling the concept of adaptive modulation. This performance lets service providers exploit the radio capacity at its maximum level thus reducing the cost associated with antennas.

## 4. References

For a comparison analysis on the referenced microwave solutions, refer to the following papers, included in the Alcatel-Lucent Q4 Quarterly Launch:


- *Wireless Backhauling: Introduction and Comparison of Hybrid, Ethernet, and Packet-Radio Microwave Architectures.*
- *A Comparison of Hybrid, Ethernet, and Packet-Radio Microwave Backhaul Networks: LTE readiness, Resource Utilization, and Deterministic Behavior.*