White Paper

When Is a Femtocell Like an Elephant?

An Investigation of Femtocells and Mobile Location Services

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The fable of the blind men and the elephant is, no doubt, an over-used metaphor. Nevertheless, it seems as apt for the topic of femotcells as any other – and I can't resist it. There are many versions, but that attributed to India's Jain sect goes along the following lines:

Six blind men are asked to determine the nature of an elephant by feeling different parts of its body. It's safe to assume that they are not familiar with the concept of an elephant, which is why they instead use concepts that are familiar to them to describe what they feel.

The blind man who feels a leg declares that the elephant is a pillar. The blind man who feels the tail declares that it is a rope. The one who feels the trunk declares it to be a tree branch. The one who feels the ear concludes it is a hand fan. The one who feels the belly says the elephant is a wall. The one who feels the tusk decides it is a solid pipe.

The moral, of course, is that the conclusions you come to in assessing anything new will depend on both which aspect of it you focus on and what you can relate it to in your past experience. It's generally not disclosed what conclusions the blind men came to when they shared their perspectives, but it would have to be assumed that they needed to both revise their prior decisions and perhaps seek to understand more about the whole subject before coming to any new conclusions.

So it is with Femtocells. In particular, this technology is generally characterized from the perspective of the user – to the extent that it feels to them just like normal cellular service. By normal cellular service, I mean the traditional switched circuit mobile telephony service (or CMRS – Common Mobile Radio Service) that became so ubiquitous in modern life over just a couple of decades. This perspective leads to the common view that Femtocells are simply more of the same – they are just normal cellular service where the cells happen to be very small.

However, there is another aspect of this technology which is just as important – actually more important in terms of highlighting the fundamental difference from traditional cellular operation that it represents. First of all, traditional cell towers are effectively owned and operated by the cellular company and interconnected using the company's own network. Femtocells however, are typically a domestic, or enterprise, appliance. They are purchased by the subscriber, installed and powered by the subscriber. This, in and of itself, is an important difference compared to the traditional business model for operating cellular service - but it is not the critical one. More

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importantly, the connectivity from the Femtocell site to the cellular network is also provided by the subscriber. Femtocells rely on the subscriber's own connection to the Internet to provide the backhaul of the cellular signaling and traffic channels to the operator's network. This particular characteristic presents a somewhat different perspective on Femtocell technology and what it actually represents.

The following diagram shows a simplified view of a residential Femtocell deployment. Note that, on the one hand, the handset thinks it is talking to a typical cell tower and, on the other hand, the cell tower is actually a domestic appliance. Calls made via this "tower" are sent through the subscriber's Internet connection before being bridged onto the circuit-switched network through the network controller.

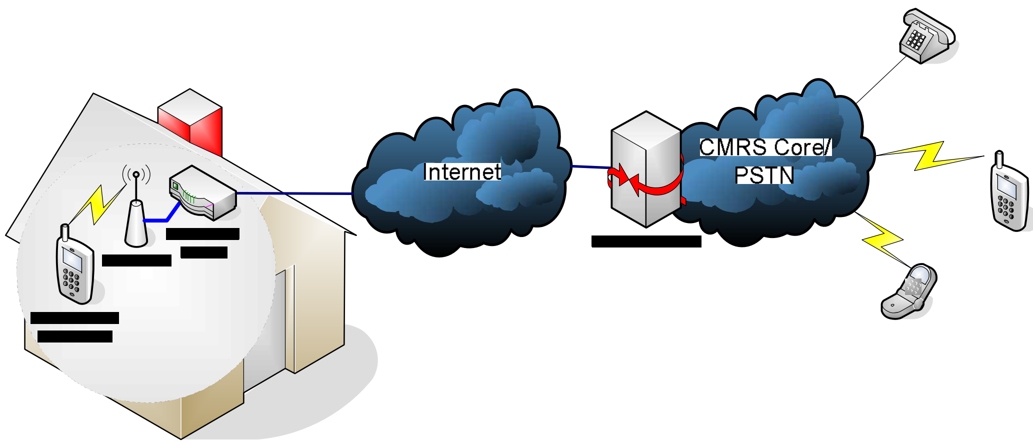

Figure 1: Residential Femtocell Deployment

There is a similar technology that is often included under the Femtocell umbrella that requires special handsets. Often referred to by the alternative label of "unlicensed mobile access" (UMA), this technology does not need to use a domestic version of a cell tower using licensed frequency spectrum. UMA typically uses commodity WiFi access point technology operating in the ISM bands. This cannot work with common cellular handsets; instead the handset needs to be dual mode such that, when in the proximity of the UMA access point, it can switch to using that radio link instead of the macro-cellular coverage. A simplified UMA arrangement is shown in the following diagram. Apart from the difference in the radio link, however, it can be noted that the overall architecture is unchanged and calls still traverse the Internet before joining the circuit switched network.

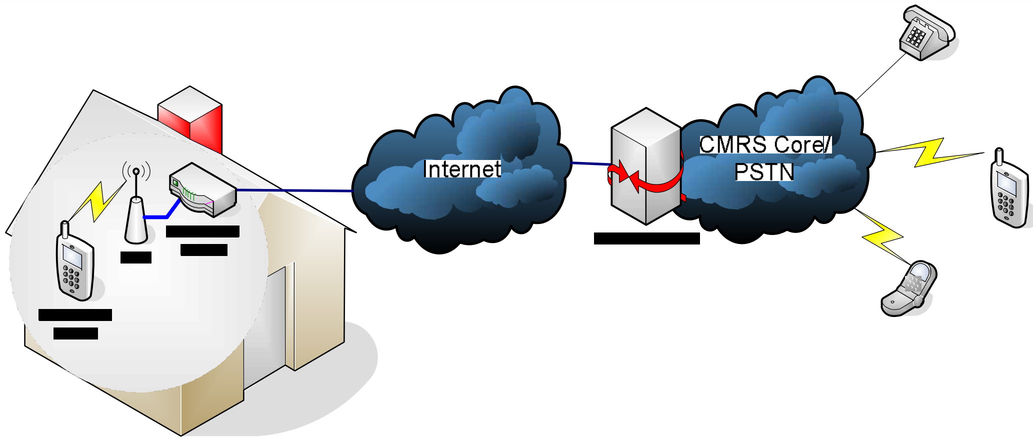

Figure 2: Unlicensed Mobile Access (UMA) Deployment

It becomes apparent that, looking at the end-to-end picture, it may be reasonable to conclude that Femtocell technology isn't simply a variation of the conventional cellular service. If we focus on the characteristic of calls being sent over the Internet and being bridged onto the PSTN then we may conclude that Femtocells belong in a somewhat different technology family. The following diagram shows a typical residential VoIP telephony arrangement.

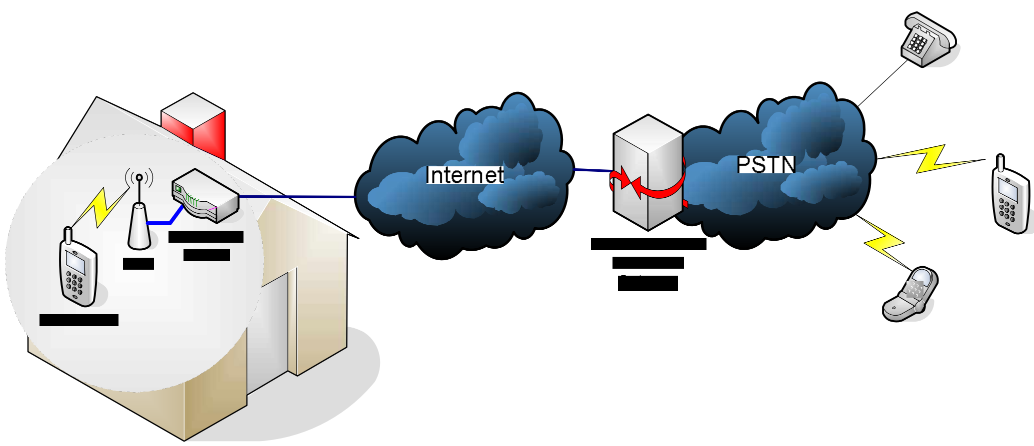

Figure 3: Residential VoIP Telephony

It is difficult to conclude that there is a significant difference between the typical VoIP scenario and the Femtocell arrangement. After all, in terms of a key characteristic "voice calls are sent over the Internet", they are effectively identical. While it is undoubtedly only a peripheral argument, some may say that the fact the handset is able to operate transparently to both the traditional cellular network as well as the Internet is a significant difference. It can be conversely argued that the true nature of the situation is that, when the handset is making a call via the traditional cellular network, it is definitely a CMRS (non-VoIP) call but when it is going via the

Femtocell, it can very reasonably be considered a VoIP call. To highlight this point, consider the following diagram of a quite common VoIP arrangement which uses standard analog telephones with an analog telephone adaptor (ATA) to connect to the Internet VoIP service.

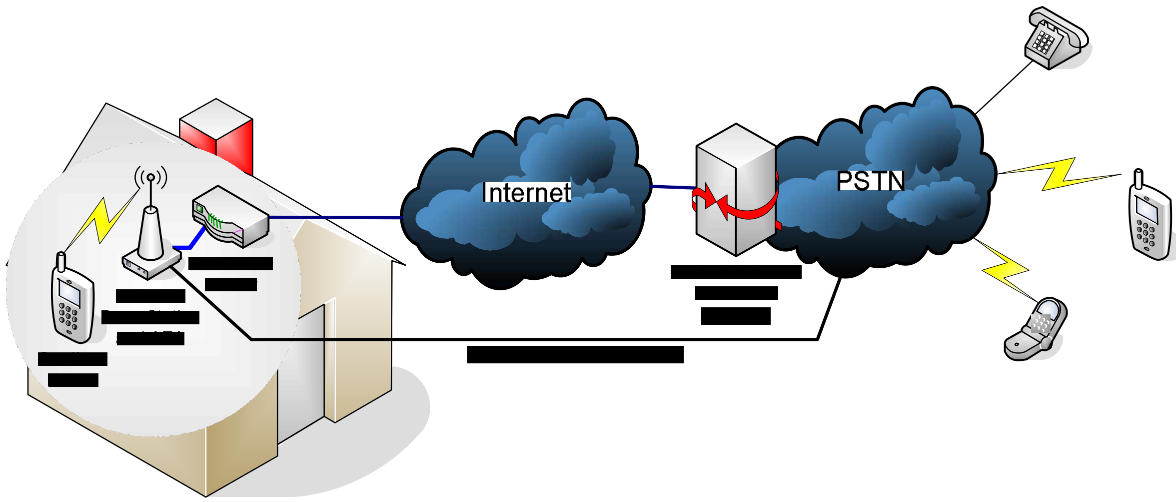

Figure 4: VoIP with POTS fallback

It is a common facility of ATA devices to include a connection to the traditional plain old telephony service (POTS) line in addition to the network connectivity to the Internet. In the event of a power failure, Internet outage, or VoIP service outage, the ATA can switch to operating over the POTS line. That is, we have a situation where the device sees nothing other than the traditional analog network interface and there is transparent switching between the traditional network and Internet telephony. It is quite reasonable, then, to ask why calls sent from Femtocells through the Internet should be considered as anything other than VoIP calls given this fundamental similarity to a service that is not touted as anything other than VoIP.

Is It All Just Academic?

It is easy to dismiss much of this as mere semantics; after all, the service does what it does and is it really important whether it is labeled as a cellular service or a VoIP service? Telecommunication services are not designed according to preconceived notions of one category versus another; they are designed to solve real problems and provide real practical value. Ultimately the goal of Femtocell technology is to provide subscribers with good transparent voice service with the additional appeal of optimal coverage and cost-effectiveness when used “at home.” What, after all, is in a name?

There is one area, however, where the distinction becomes critically important – life and death important. That is the area of emergency calling or 9-1-1 as it is known in the USA.

From a regulatory perspective, there is a big difference between what is expected and required of US cellular providers with respect to 9-1-1 and what is expected and required of VoIP calls to 9-1-1. Cellular providers have to support enhanced 9-1-1 (E9-1-1) which includes the delivery of accurate caller location information to the public safety answering point (PSAP). Indeed, it is a challenge in the US to get the call to the right PSAP without having determined some sort of accurate location information before the call is even routed.

In comparison, the regulatory impositions associated with VoIP are only rudimentary. Since an FCC docket that was issued in 2006 [1], there has been a requirement for VoIP providers to at least support 9-1-1 calls. Nevertheless, it was recognized then that VoIP providers have no necessary relationship with the caller's physical connectivity to the Internet. In contrast to POTS and CMRS operators, there is no mechanism that allows VoIP providers to know the point of network connection and resolve a corresponding location. As such, the 1996 docket declared that, for now, it is sufficient for the VoIP provider to put the onus for the provision of location information onto the subscribers. As long as the VoIP provider has a mechanism, such as a web page, that allows the subscriber to update the nominal location they expect calls to come from then the provider is meeting its obligations. There was a brief period after the docket came into force, where VoIP providers had to cancel the service of any subscribers that did not acknowledge and accept this aspect of their subscription. That phase is long finished and the arrangement of manual location reporting and best-effort 9-1-1 call delivery has become the status-quo for VoIP services – at least in the near term.

In contrast to the above, cellular operators have strict accuracy requirements for location information, call delivery, and information delivery. Typical requirements are 50 meter and 100 meter accuracy at the 67th and 95th percentiles respectively for location methods involving the handset. A recent notice of public rule making (NPRM) from the FCC [2] presages even more comprehensive and strict requirements.

The 9-1-1 Challenge

Given the considerable difference in regulatory imposition on a VoIP service provider versus a CMRS provider, it must be tempting for the cellular operator to claim that emergency calls originating on Femtocells are really a case of VoIP and, so, their traditional phase 2 obligations simply don't apply. The service may look like normal cellular to the user but the same "walks like a duck" argument has not been enough to ensure that a standard form factor phone connected to a VoIP ATA on a Wireline broadband connection should deliver the same E9-1-1 service that a POTS line does. Indeed, the argument of the VoIP industry that calls made in this way are participating in an "information service" rather than a traditional telephony service have been enough to keep the hounds of regulation substantially at bay for now.

It must be said that, to their credit, the CMRS operators that have deployed Femtocell technology in the US have been generally proactive in ensuring that the best efforts are made to provide a comparable level of E9-1-1 service for their subscribers. This includes facilities for automatic location determination, call routing to the correct PSAP, and presentation of the location information for display and dispatch at the PSAP. Nevertheless, Femtocell technology, given its architectural equivalence to VoIP, has the same fundamental challenges with respect to 9-1-1 that make it difficult for a traditional VoIP provider. So what are those challenges? They can be summed up with one word: "Location."

Most modern societies aspire to having a reliable emergency calling service that is ubiquitously and uniformly accessible for contacting key responders such as Police, Fire, and Ambulance. It is of fundamental importance to such a service that the location of the caller is available in this process – and this is nowhere truer than in the United States. In the US, there are six or seven thousand individual PSAPs operating in a highly devolved and independent fashion – sometimes managed at the individual county level. When a 9-1-1 call is initiated, before it is even answered, location information is critical to ensuring that the call is sent to the PSAP whose jurisdiction covers the location of the caller. Of course, once this is done, it is important that the location information be delivered to the PSAP for display to the call taker. Particularly with the advent of mobile telephony, where callers frequently aren't sure how to describe their location, this information is often of life and death importance.

It is often assumed that, when it comes to VoIP, it must be the provider of the VoIP service who is responsible for providing E9-1-1 capabilities – including the fundamental function of determining the location of the caller. The challenge for the generic VoIP provider is that they generally have no readily available mechanism to do that.

Generic VoIP services exist on the Internet and, like search engines and social networking sites, can be reached from any convenient point of Internet access. This is part of the enormous appeal and flexibility of VoIP services. At the same time, however, a VoIP service has no reliable means of knowing how a client is accessing the service, let alone which network or exactly where on the network it may be doing so. A good deal of work has been done in industry groups and standards bodies on finding a solution to the delivery of emergency calls over the Internet and a significant characteristic of all solution architectures is that it is recognized that the access network is the right place to determine location rather than the remote and decoupled VoIP service. Indeed, it is notable that the main value of a VoIP service is in terms of routing calls to remote peers or bridging them onto the PSTN. Assuming a VoIP device already knows the destination address of a PSAP, the VoIP service provider (VSP) actually has no value to add to the establishment of the emergency call.

Looking at common architectural solutions for Next Generation Network (NGN) Emergency Services:

1. NENA i3 [3] assumes the presence of a Location Information Server (LIS) in the access network to provide the location service.
2. IETF/ECRIT [4] assumes a location service, accessible by the calling device, that is used prior to call establishment.
3. 3GPP IP Multimedia Subsystem (IMS) [5] assumes the location retrieval function (LRF) that can reach into the visited network for location determination.

For example, a simple direct emergency call using the i3 NGN (or IETF ECRIT) architecture is shown in the following diagram

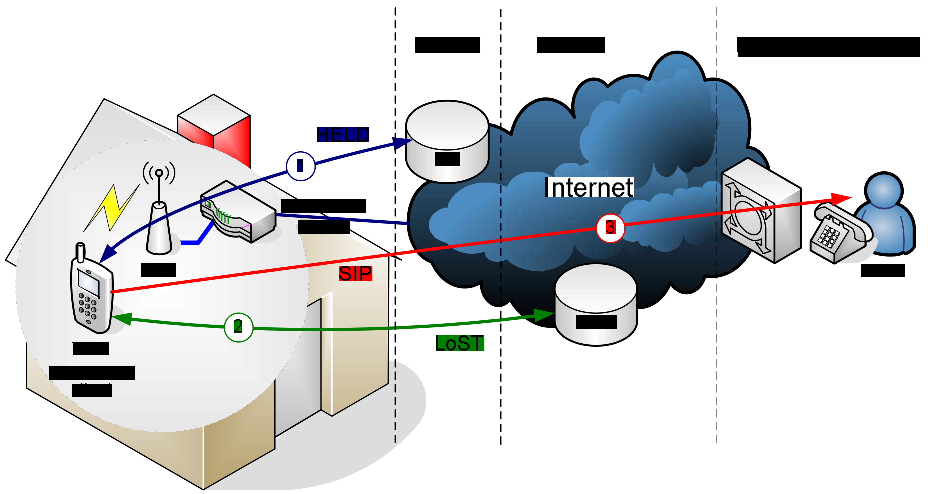

Figure 5: NGN Emergency Call Procedure

When the user of an Internet-connected device decides to make an emergency call, location is determined via (1) a query to the LIS in the access network. HTTP Enabled Location Delivery (HELD) is a protocol that can be used to interact with a LIS to obtain location information. Armed with the location information, the device can determine the identity and address of the PSAP serving that location by (2) reference to a service called Location to Service Translation (LoST) using the associated protocol. The LoST server is essentially a spatial database that relates areas of location to the URI at which a nominated service (in this case 9-1-1) can be reached. Having determined the URI that corresponds to the correct serving PSAP, the device can (3) initiate an emergency call directly to the emergency service using the Session Initiation Protocol (SIP). Note that a VoIP service provider is not necessary for this procedure. The architecture permits location to be provided in the most suitable form. A LIS in a Wireline broadband network may provide a residential street address (also referred to as civic address form) while a LIS associated with a 4G mobile network may provide a geographic area of uncertainty that incorporates latitude and longitude information (referred to as geodetic form).

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Femtocells as a VoIP Solution

Returning to the notion that Femtocell technology is architecturally equivalent to a VoIP deployment, we can see that the same issues associated with location determination arise. Certainly the service comes with a specific piece of hardware that provides a physical presence associated with the service. However, this is often also the case with common VoIP services where the VoIP client is incorporated in a locked ATA or residential router. This particular characteristic does not represent a panacea to the challenge of location determination as has been tragically demonstrated [6] since the device is owned by the subscriber and is inherently capable of being moved. Numerous options exist to provide some sort of location facility for such devices and these include user-configurable location, incorporating signals that may be seen from the operator's traditional cellular infrastructure, through to incorporating GPS capabilities into the devices themselves. All of these solutions are subject to some sort of failure where location is either unavailable or incorrect. This is in contrast to traditional CMRS deployments where a reliable fallback technology is assumed to always exist and which will provide some sort of representative location fix with an indication of associated uncertainty.

By the same token, since they have effectively outsourced the public network connectivity to the subscriber, the Femtocell operator no longer controls that access network asset which is fundamental to this reliable determination of location information. In other words, they are effectively in the same position as any general VoIP provider with respect to the challenge of being certain about the location from which emergency calls originate.

Ultimately, a solution for reliable location for Femtocells – not surprisingly – can be identified as the same solution for generic VoIP services. The reliable location service should be sourced from the physical access network. The physical access network in the case of Femtocell technology is the broadband access that is provided by the subscriber.

Looking at the diagram below, it can be seen that the option for location determination by Femtocells is the same as that for generic VoIP services. For example, a Femtocell can access and utilize the LIS in a wired broadband access network using the HELD protocol to obtain location information.

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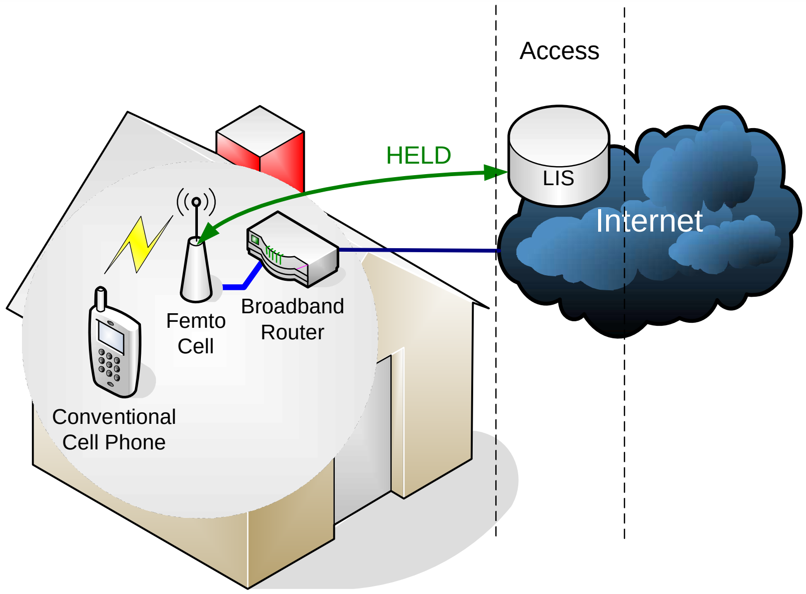

Figure 6: Femtocell taking advantage of NGN location service

It is a matter of implementation for the Femtocell operator how they use the location information in the processing of emergency calls. It may feed into its existing CMRS emergency infrastructure. Alternatively it has the option of adopting full NGN emergency call processing using LoST and the SIP-addressable PSAP infrastructure. A valid consideration is whether the geodetic form common to CMRS emergency location reporting is really appropriate in a context where the call is originating from a Wireline broadband connection anyway.

Conclusion

The assessment of what is appropriate for Femtocell deployment hinges on how the technology is perceived. When regarded as a simple extension of the existing CMRS, challenges arise in terms of meeting existing regulatory obligations. If a Femtocell is regarded as a variation on a VoIP device, then the consequences and perceived solutions can be quite different.

In many respects Femtocell technology represents a bridge between the old switched-circuit world of the PSTN and the current generation of IP-based packet communications exemplified by the Internet. It provides a means of continuing to use circuit switching core network assets owned by CMRS operators while providing a seamless user experience and taking advantage of the wealth of bandwidth available for simple telephony in the typical residential broadband connection.

The question has to be asked what the life time of this bridging technology is. The new 4G wireless network technologies of WiMAX and LTE do not support circuit services. Traditional telephony cannot be used with these new generations of access networks; all voice services will be VoIP in nature using IMS or more generic VoIP technologies. At the same time, devices are quickly converging to use generic computing platforms and operating systems. Device form factor is a matter of convenience rather than fundamentally defining a technology category. Similarly, devices are increasingly multi-access capable supporting wide-area wireless broadband, WiFi, and Ethernet as a common practise with the user being in control of which technology provides the optimum experience and cost performance. Modern devices are much more adroit when it comes to shifting between access technologies anyway. In an environment such as this, it is reasonable to ask whether a device really needs a Femtocell to facilitate such access-switching.

The interesting question is just what the dynamics will be in the short term. As broadband networks migrate to NGN services that incorporate LIS capabilities, Femtocell deployments continue to occur and devices continue to evolve and be churned out of the market. The order of events and the public visibility of the functions of different technologies will determine the perceptions that prevail. It will be fascinating to watch – and only then will the true form of the elephant become clear.

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