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Hype Cycle for Mobile Device Technologies, 2012

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This Hype Cycle examines the status of, and prospects for, various mobile device technologies. It advises device vendors, mobile operators, application providers and others on the maturity of these technologies and their use.

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What You Need to Know

Advancements in mobile technology and interfaces are driving device upgrades by offering a richer consumer experience. The introduction of Apple's iPhone and iPad has ushered in a new era of competition. Vendors are focusing more on delivering technology to consumers in a meaningful way — looking for ways to combine design, technology and device usability more effectively. The mobile

device landscape has changed as a result. The product spectrum is widening, and the key differentiator is no longer singularly focused on hardware or software alone. It is the combination of hardware and software and the underlying ecosystem that will determine success. Device manufacturers need to continue to focus on those technologies that deliver the highest ROI by enriching the user's overall experience to the point that users will pay a premium for them. Advances in key technologies — such as manufacturing processes, radio technologies, chip fabrication, processors, memory, displays and user interfaces (UIs) — will dramatically change the size, shape and capability of mobile devices during the next 10 years.

The Hype Cycle

The mobile market has traditionally focused on mobile phones. Increases in connectivity, usability and functionality have expanded this market to other domains such as smartphones, tablets, portable media players and even handheld gaming devices. Initially, many of these newly connected devices were stand-alone, limited-function devices. Now, these multifunctional, more fully featured devices serve to keep users entertained, up-to-date with information, in touch with family and friends, and expanding their productivity. This has allowed consumers to do more outside the home and office in both their personal and professional lives. This Hype Cycle (see Figure 1) is a window into the innovations we will see in this industry that will enable this continuous metamorphosis of mobility.

The added functionality of these devices is transforming the way consumers use and interact with technology. In turn, it is driving industry innovation that will foster this usage and promote new usage patterns. Trends in UIs, display technologies and power consumption continue to be at the forefront of this market. Progress continues to be made in terms of wireless connectivity, power usage, user experiences and display technology.

Wireless Trends

The growing trend of mobile, multipurpose devices interacting within an ecosystem has highlighted the need for wireless technologies that provide a seamless customer experience. There are numerous WLAN initiatives working toward this goal. Technologies such as cellular to Wi-Fi authentication allow consumers to move freely between Wi-Fi and cellular networks for their voice and data calls. Furthermore, the strong interest in mobility and video has driven the need for harmonization of wireless video technologies. At the application layer, we expect increasing efforts to coalesce around the Miracast (formerly Wi-Fi Display) standard — allowing for better interoperability between different devices for peer-to-peer video streaming.

NFC is also increasing in prominence and adoption. Aside from Apple, all the leading smartphone OS vendors are supporting NFC as of the end of 2011. Moreover, despite the slight uptick in hype driven by Google/Android last year for NFC, the technology continues to languish, and is sliding toward the trough. We continue to believe this has high-benefit potential, but requires compelling solutions before becoming widely embraced.

Power Technology and Usage Trends

Although research on improving lithium ion batteries for mobile devices continues, most efficiencies are gained through power management software. Regardless, wireless devices continue to add features and functionality and demand more power. Displays and processors continue to be the two most taxing elements on power supplies. In light of current battery technology limitations, vendors have introduced a number of different solutions to address these issues.

- Lower-power display solutions such as reflective and electrofluidic/electrowetted displays and electronic paper
- Alternative power sources such as micro fuel cells
- Alternative charging methods such as solar power mobile devices and wireless power

Display Trends

This is a rapidly evolving area for mobile devices and consumer electronics in general. With displays being the most prominent feature on mobile devices, vendors demand the most robust displays to showcase their "halo" devices. Moreover, displays continue to have a significant drain on battery life. Advancements in current technologies, as well as new display technologies, are focused on addressing these key issues. Beyond this, vendors are also looking to provide display innovation beyond just having the sharpest screens with large color palettes. This includes research into technologies such as volumetric and holographic display as well as 3D.

Aside from 3D (which has yet to prove itself even in the larger, consumer market), most of these display technologies are either 10 or more years out from mainstream adoption, or will be limited to specific markets. In the near- to midterm, active matrix organic light-emitting diode (AMOLED) will be the most viable mass market alternative to LCD screen technology.

User Experience Trends

User experiences have become a crucial success factor for mobile devices. As we mentioned above, this is more than just hardware or software. It involves how users interact (voice, touch and gesture) with their devices as well as the applications (browsers, augmented reality, location-based services, etc.) driving this interactivity.

Multitouch and gesture control are the only two transformational technologies on this Hype Cycle — highlight the importance of the user experience and how drastically these two technologies have and are expected to change the way consumers interact with their mobile devices. Voice recognition has also evolved and received some hype in the past year because of Apple's Siri, and to a lesser extent, Samsung's S Voice. In turn, this has led to a renewed interest in speech recognition in mobile devices. Similarly, the Wii and Kinect have done the same for gesture. Despite the buzz received in voice and gesture, further progress and wider adoption has been limited. On mobile devices, we expect these technologies to continue to be complementary to the multitouch environment.

Virtualization has also reached the peak of hype. Announcements such as Nvidia's cloud-based GPU have further fueled the excitement around this technology. For consumers, this technology promises to significantly change the cloud-based gaming experience. For enterprises, it signifies a meaningful shift in how users interface with and experience graphics-accelerated content creation applications and server-hosted virtualization.

Trends around positioning and location continue to provide high benefit to users. Although past the peak of hype, augmented reality (AR) will be a combination of all these technologies — eventually providing a rich, seamless consumer experience. This year's buzz around Project Glass hints at the future of AR — where it won't be a distinct functionality, but rather a digitally richer way for people to interact will their environment.

Mobility continues to develop and expand beyond its traditional roots. In turn, we have added new technologies to this Hype Cycle to reflect this evolution:

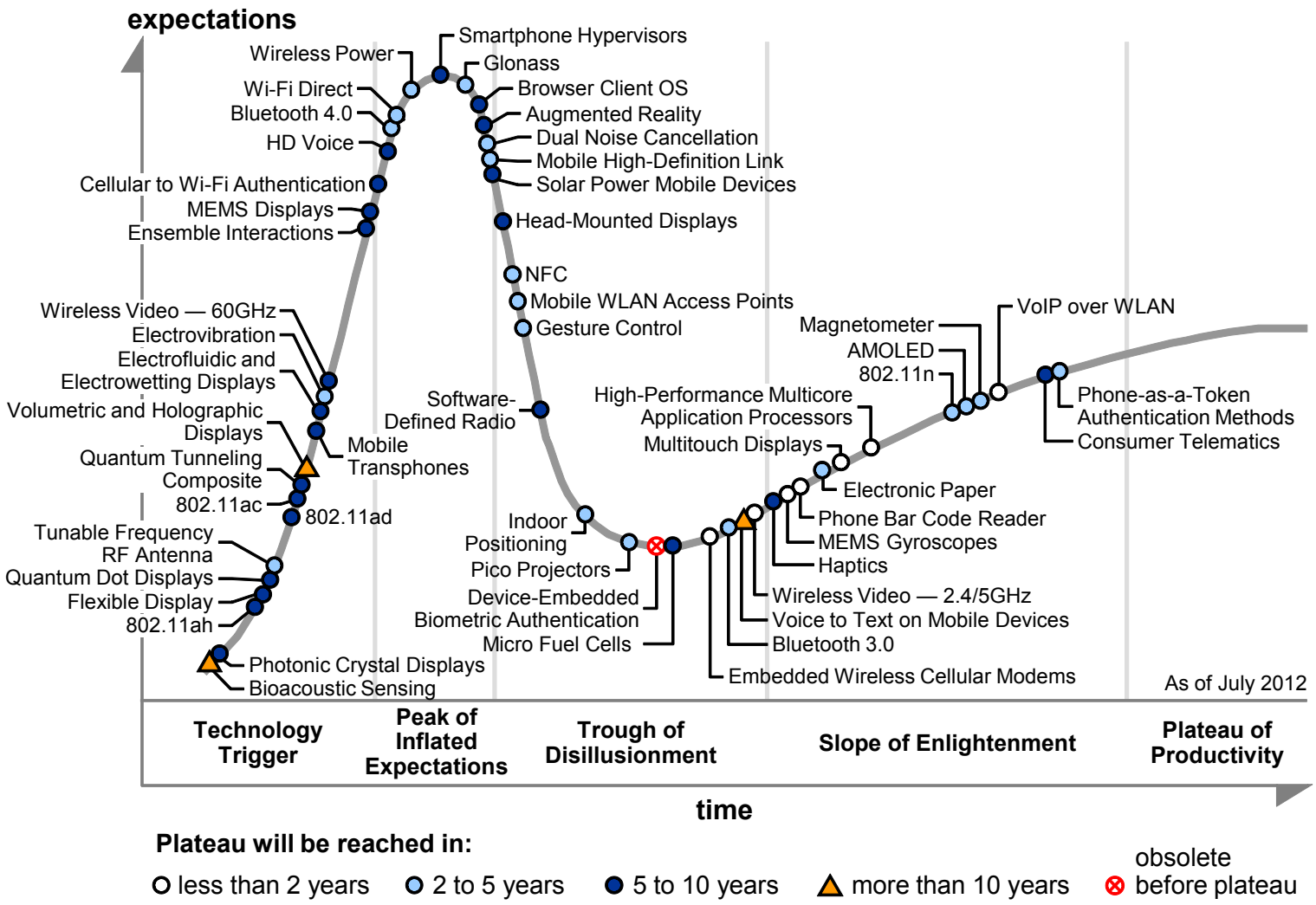
- 802.11ah
- IPS display
- Tunable RF antenna
- Flexible display
- Browser client OS

The following terms have been updated to more accurately reflect the technologies analyzed:

- "Phone-based authentication methods" has been changed to "phone-as-a-token authentication methods."
- "Multitouch" has been changed to "multitouch displays."
- "Gesture recognition" has been changed to "gesture control."
- "Wi-Fi personal-area networks" has been removed. "Wi-Fi direct" has been updated and replaces "Wi-Fi personal-area networks."
- "BT 4.0" has been repositioned because product introductions around this technology have not met previous expectations. The appearance of BT 4.0 in the iPhone 4S will subsequently drive hype to the Peak of Inflated Expectations.
- "Device-embedded biometric authentication" remains in the Trough of Disillusionment, but we now consider it to be obsolete before it reaches plateau as an enterprise technology because of varying support among endpoint devices and lack of adoption.
- We have also split "haptics" into two — a general profile and one specific to mobile devices. We did this to reflect the disparity in adoption of haptics in mobile compared with more general use in industrial, gaming and general consumer electronics.
- "Mobile data intelligence and embedded cellular data" has been removed. It continues to be in the "Hype Cycle for Wireless Devices, Software and Services, 2012" and "Hype Cycle for

Consumer Services and Mobile Applications, 2012," respectively — as it is a more applicable technology for that Hype Cycle.

Figure 1. Hype Cycle for Mobile Device Technologies, 2012



Source: Gartner (July 2012)

The Priority Matrix

Priority Matrix Mobile Devices

Most of the technologies on the Hype Cycle will mature in two to five years and will have at least a moderate impact on the mobile devices industry.

No new technology adds to the three that were highlighted last year as having a transformational impact on the mobile devices industry:

- **Multitouch and gesture:** These technologies will impact many areas, ranging from computing to gaming, and change the way users interact with content.
- **Bioacoustic sensing and quantum tunneling composite:** These technologies could improve the user experience because interaction options would no longer be limited by the physical hardware of the device. Quantum tunneling composite (QTC) is seen as transformational because it can be incorporated in a wide range of different products — everything from clothes to credit cards — not just switches and consumer electronics controls. The technology's flexibility and low cost mean it has broad potential for applications beyond integration in handsets and consumer electronics — into fields and industries such as sports, healthcare, automotive, robotics and industrial machinery.
- **Software-defined radio:** This technology has the potential to reduce device costs and complexity, as less radio hardware would be required to support many protocols. It also could enable advanced devices that dynamically negotiate protocol and spectrum use, depending on their needs and the needs of other devices in the vicinity.

Most technologies on the Mobile Devices Hype Cycle saw very little if no movement at all over the past 12 months. This is a reflection of the higher bar that many of these technologies are trying to achieve in areas such as screen optimization, power management and user interfaces.

Technologies that have progressed greatly in the past 12 months:

- Pico projectors
- Cellular to Wi-Fi authentication
- MEMS gyroscopes

We expect the following technologies to make the most progress during the coming year:

- Indoor positioning
- Location-based services
- Flexible displays
- Wireless video

Figure 2. Priority Matrix for Mobile Device Technologies, 2012

benefit	years to mainstream adoption			
	less than 2 years	2 to 5 years	5 to 10 years	more than 10 years
transformational	**Multitouch Displays**	Gesture Control	Quantum Tunneling Composite Software-Defined Radio	Bioacoustic Sensing
high	High-Performance Multicore Application Processors	Bluetooth 4.0 Electronic Paper Electrovibration Indoor Positioning Magnetometer Mobile WLAN Access Points NFC Wireless Power	802.11ad 802.11ah Augmented Reality Cellular to Wi-Fi Authentication Consumer Telematics Electrofluidic and Electrowetting Displays Micro Fuel Cells	Voice to Text on Mobile Devices
moderate	Embedded Wireless Cellular Modems MEMS Gyroscopes Phone Bar Code Reader Wireless Video — 2.4/5GHz	802.11n AMOLED Dual Noise Cancellation Glonass Mobile High-Definition Link Phone-as-a-Token Authentication Methods Pico Projectors Tunable Frequency RF Antenna Wi-Fi Direct	Ensemble Interactions Flexible Display HD Voice Head-Mounted Displays MEMS Displays Mobile Transphones Photonic Crystal Displays Quantum Dot Displays Smartphone Hypervisors Wireless Video — 60GHz	
low	VoIP Over WLAN	Bluetooth 3.0	802.11ac Browser Client OS Haptics Solar Power Mobile Devices	Volumetric and Holographic Displays

As of July 2012

Source: Gartner (July 2012)

Off The Hype Cycle

Mobile browsers already reached the Plateau of Productivity and moved off the Hype Cycle.

On the Rise

Bioacoustic Sensing

Analysis By: Roberta Cozza

Definition: Skinput provides a new input technique based on bioacoustic sensing technology that allows the skin to be used as a finger input surface. When a finger taps on the skin, the impact creates acoustic signals, which can be captured by a bioacoustic sensing device.

Variations in bone density, size and the different filtering effects created by soft tissues and joints, create distinct acoustic locations of signals, which are sensed, processed and classified by software. Interactive capabilities can be linked to different locations on the body.

Position and Adoption Speed Justification: This technology is being developed by researchers for Microsoft and the Human-Computer Interaction Institute of Carnegie Mellon University in Pittsburgh. In a prototype system, researchers focused on touch inputs on the arm and hand, and created an armband device for sensing. They evaluated different input locations, such as the fingertips and along the forearm.

The technology can also be integrated to augment the experience with a pico projector that projects dynamic graphical interfaces onto the hand or forearm. For example, a telephone keypad can be projected onto the palm of the hand, allowing real-time dialing without the use of a mobile phone.

Researchers also developed a scrolling interface for projection onto the forearm. Users tap the top or bottom of the UI to scroll up or down or go back one level in the UI hierarchy. Users can perform a simple pinching gesture with their thumb and fingers. Accuracy of 95.5% for five input locations on the whole arm has been demonstrated.

The technology is in the early stages of development and future efforts will need to improve on the non-invasiveness of wearable bioacoustic sensor devices. Also, the disturbance from acoustic signals coming from other motions of the body will need to be reduced, particularly in walking or jogging scenarios (such as operating an MP3 player using Skinput while running).

The input method is limited to quick skin taps, which in its current form does not permit more elaborate common gestures such as sliding or dragging. Additionally, body mass index fluctuations can decrease sensing accuracy and there is a high "learning curve" in setting up the solution.

Since its first appearance at Microsoft TechFest 2010, this project is still under development with no commercial product available or expected in the next five years at least. Latest developments include a focus on a significantly decreased size of armband.

User Advice: Advances in this technology should be monitored and considered in scenarios where users can benefit from always-available and easily-accessible input without direct access to the keypad on a device, such as a mobile phone or portable music player.

Business Impact: Using the human body as an input surface is an interesting concept for UIs. It could enable consumers to use larger and easily accessible additional input surface areas for interaction, compared with the small surface areas offered by the touchscreens on handsets.

Users could benefit by having large extra surfaces for input without needing to carry extra items. In addition, this type of input would allow accurate "eyes free" touch interactions, because of our natural sense of body configuration (proprioception). Unlike other external input devices, most interactions could be performed without looking at the surface of a device. Experiments have also demonstrated a good level of accuracy in the input. Other external input approaches, such as smart fabrics or wearable computing, typically require an input device to be built into a piece of clothing, which is more complex.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Microsoft

Photonic Crystal Displays

Analysis By: Roberta Cozza

Definition: Photonic crystal displays are reflective displays made of photonic crystalline materials that can be constructed and designed to manipulate the propagation of light (photons).

Position and Adoption Speed Justification: As a display technology, photonic crystals are currently being used in laboratories to create full-color flexible electronic paper displays, outdoor advertising displays or small reflective screens for mobile devices and consumer electronics. In such displays the spacing between the photonic crystals can be controlled so that they can reflect colors across the entire visible spectrum when an external stimulus is applied, such as electrical voltage or a magnetic field.

The whole spectrum of colors can be produced using only incident light. As a result, expensive color filters (like those found in most of the display technologies on the market) are no longer needed. As the displays are reflective, no additional power consumption is needed for backlighting, unlike transflective displays. However, being reflective means viewability is affected when in poor light conditions.

At present, the most visible use of photonic crystals in display technology comes from the Canadian company Opalux, which uses photonic crystals with the potential to produce color-flexible electronic paper displays through its P-Ink technology. Commercialization of such displays is expected to be at least five years away and significant work is still needed in photonic crystal display research to improve viewing angles for each color, control single pixel saturation and color intensity.

Pixel switching speed is another key area requiring major improvement, as current switching times are still too long to support video. Alternative color display technologies will also increase competitive pressure among manufacturers. Some (like Samsung/Liquavista and Qualcomm's microelectromechanical systems [MEMs] displays) are incorporating electrowetting technology (where small electrical charges are used to move colored oil within each pixel).

More competition will also come from LCD manufacturers improving color support for devices such as media tablets and smartphones, where enhanced e-book content can be consumed.

User Advice: Research and development in photonic crystals used as a display technology is in its very early stages of development. Consumer device vendors should monitor research in this area to identify future opportunities.

Business Impact: Displays using photonic crystals can offer the competitive advantage of enabling less power consumption, as they require no backlighting. In addition, the color generated in each pixel can be maintained for a long time (days) without requiring additional power. With no backlight, high contrast and reflectivity, outdoor viewing quality is greatly improved.

Additionally, there is no need for expensive color filters, as found in most display technologies, which reduces costs. Ultimately, the fact that a single material can be used to produce the entire spectrum of colors can simplify the manufacturing processes.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Opalux

802.11ah

Analysis By: Mark Hung

Definition: 802.11ah is a new Wi-Fi standard that is being developed by the Institute of Electrical and Electronics Engineers (IEEE), targeting the emerging low-power Internet of Things (IoT) market. It will operate in the unlicensed sub-1GHz bands, excluding the TV white space bands. Like the current 802.11 standards, it will use orthogonal frequency division multiplexing (OFDM) as the modulation scheme. It is expected to have a lower data rate (approximately 100 Kbps) and longer range (up to 1 kilometer [km]) than the current Wi-Fi technologies. Final ratification of the standard is expected by mid-2015.

Position and Adoption Speed Justification: 802.11ah has just started to be specified in the IEEE TGah working group. With the first letter ballot not expected until 2013, the standard is still in an emerging stage.

User Advice: "Thing" makers that are looking to bring products to the market in the 2013 through 2014 time frame are advised to evaluate 802.11ah before being locked into an existing standard, such as ZigBee, or proprietary sub-1GHz technologies. Vendors that have a more immediate need are advised to either actively participate in the IEEE activities or monitor it closely to see if their current implementations can be made forward-compatible. Given that 802.11ah will fall under the overall Wi-Fi umbrella, it is expected that it will be compatible with the existing Wi-Fi infrastructure. It may also be able to leverage Wi-Fi's economies of scale to drive down costs.

Business Impact: 802.11ah has the potential to significantly grow the Wi-Fi market from its existing computing and mobile platforms to the "greenfield" IoT market. However, since it is still in the early stages of development, it risks being too late to the market and losing out to competing technologies, such as ZigBee or even low-power versions of 802.11n.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Aclara; Broadcom; Intel; Marvell Technology Group; Qualcomm Atheros

Flexible Display

Analysis By: Anshul Gupta; CK Lu

Definition: Flexible displays are flat computing screen panels constructed of thin/flexible substrate that can be bent, rolled, folded or flexed without losing functionality. Flexible substrate that is used to replace conventional glass substrate can be plastic or thin glass.

Position and Adoption Speed Justification: Flexible displays include many components and supporting technologies such as flexible substrates, conducting transparent conducting oxides/ polymers, electro-optic and reflecting materials, inorganic and organic electronics, and packaging technologies. It also requires new manufacturing processes such as roll-to-roll manufacturing, coating and printing technology. Flexible display is a combination of all these components, which must be co-developed to function efficiently. Multiple companies have been working on this futuristic concept to deliver flexible displays and have used components using various technologies. There is no standard flexible display with standard component technology yet as technology is still evolving at both the component and display levels.

Flexible display technology can result in many compelling applications such as:

- Large wall-sized reflective screens for use in conference room settings that could be rolled away when not in use
- Small portable rollable displays
- Irregular-shaped displays used in the steering wheel of an automobile
- Conformed displays integrated in an automobile filling up the entire dashboard
- Wristband displays that are permanently conformed throughout their lifetime

Flexible displays could be also deployed in bendable phones or tablets. We expect mobile devices with flexible displays to emerge in 2013.

User Advice: Although flexible display will be a reality, complete flexible devices may still take more time. So a consumer device with flexible display is a near-term possibility. However, a wearable wristband smartphone is still years away as that would depend on other parts such as processors, casings and batteries.

Costly, time-consuming manufacturing processes will keep costs high. Flexible displays may likely replace glass-based displays for many applications but it will be difficult for flexible displays to compete solely on cost alone in the inexpensive and small display module market or in the high-end, high-performance market (such as desktop and laptop screens). Costs can be brought down once displays can be manufactured using roll-to-roll processing instead of batch processing.

Business Impact: Flexible display could bring together laptops, tablets and smartphones into a single device. You could unroll or unfold the device to just the size needed based on what they needed to do. For instance, only unfold it to three inches by five inches to make a phone call or open it up all the way to a 10-inch display for a table, or 15 inches for a laptop and typing surface.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Quantum Dot Displays

Analysis By: Roberta Cozza

Definition: Quantum dots are nanocrystals made from types of semiconductor that emit colored light. They are very small, with a diameter ranging from two to 10 nanometers. The different colors emitted can be finely tuned by changing the size of the quantum dots and manipulating their chemical composition.

Position and Adoption Speed Justification: As with organic light-emitting diode (OLED) screens, the light in quantum dot displays is self-emitted, meaning that they do not require backlights and color filters like LCD displays.

When quantum dots are used in existing display technology, such as the LEDs in LCD backlights, they can improve power efficiency by reducing the number of diodes required to achieve similar levels of brightness. Because quantum dots can be tuned very precisely to emit specific colors, they also improve the overall purity of color and color rendering compared with OLED screens, for example.

The composition of these quantum particles means they are soluble, which allows greater manufacturing flexibility because they can be used with solution processing techniques such as spin coating, roll-to-roll processes and printing on large areas and flexible substrates.

In contrast, OLED screen manufacturing involves more complex techniques. Quantum dot displays are in the R&D phase and at least five to 10 years away from commercial availability as stand-alone products. Adoption to complement or supplement existing light-emitting diode (LED) and LCD technology is more mature in comparison. Recently, 3M and Nanosys have announced a partnership to commercialize a quantum-dot-based technology to improve color performance in LCDs.

Some companies, such as QD Vision, have produced prototypes and quantum-dot-based solutions to improve existing OLED technology with their quantum dot LED products. Samsung Electronics' researchers have revealed a color four-inch quantum dot prototype panel. Quantum-dot-based displays are still expensive to manufacture compared with other display technologies such as OLEDs and LCDs. Most quantum dots are made of elements such as cadmium — which are highly

toxic — making their presence in future commercial applications problematic. Some companies, such as Nanoco Group, are developing quantum dots that are free of heavy metals.

User Advice: R&D into quantum dots used as a display technology is at the prototype stage. Device vendors should monitor research in this area to identify future opportunities to use quantum dot applications to improve existing display technologies.

Business Impact: Displays are an essential part of the user experience for mobile devices and smartphones. As video, Web browsing, gaming and navigation apps become more sophisticated on mobile phones, display performance considerations play a key role — especially in relation to the high demands they place on the battery.

Quantum-dot-based displays promise key advantages over existing display technologies (such as LCDs and OLEDs), with improved power consumption over LCDs, better color rendering and more flexible manufacturing processes. R&D into quantum dots is vast and companies have developed some commercial quantum dot solutions — mostly around LEDs, lighting and security applications.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Evident Technologies; LG Display; Nanosys; QD Vision; Samsung Electronics

Tunable Frequency RF Antenna

Analysis By: Anshul Gupta

Definition: A tunable radio frequency (RF) antenna supports tunable architecture that allows the frequency of antenna resonance to be moved up or down electronically to support different network frequency bands used in cellular technology.

Position and Adoption Speed Justification: There are multiple technologies offering tunable RF for mobile devices' antenna tuning requirements, including:

- RF micro-electromechanical systems (MEMS) from WiSpry. Other players offering similar technology are TDK-EPC, Sony, Omron, RF Micro Devices, Kinetics and DelfMEMS. RF MEMs from WiSpry have been used in Samsung's "Focus Flash" device.
- Paratek's barium strontium titanate (BST) tunable integrated circuits. Research In Motion acquired Paratek in early 2012.
- Peregrine Semiconductor's DuNE antenna tuning devices, based on its silicon-on-sapphire switch technology.

The most significant benefit of tunable RF is the option of antenna tuning and matching.

In current mobile devices' RF architecture, multiple standards and functions coexist with multiple RF paths, which are set in parallel. This architecture is not well-suited to support evolving mobile devices as it raises the number of components, and the size, cost and power consumption of mobile devices. Reconfigurable architectures are best suited to increasing the functionality of phones while maintaining size, cost and power consumption. Tunable RF makes this possible by offering antenna tuning and matching features — the most significant benefits of tunable RF.

There are other benefits of tunable RF, which have allowed for the wider adoption of this technology in mobile devices, such as:

- Eliminating signal dropout issues because of holding devices in certain ways
- Improving antenna efficiency resulting in increased data transmission rates
- Allowing smaller antennas, which results in even thinner mobile devices

User Advice: The circuit of tunable RFs must be linear to avoid generating intermodulation distortions. The whole RF circuit must have low power consumption, and be small, rugged and reliable.

Business Impact: Tunable frequency RF antennas will enable compact devices, and reduce power consumption that will lead to longer battery life and reduced manufacturing costs.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: delfMEMS; Kinetics; Omron; Peregrine Semiconductor; Research In Motion; WiSpry

802.11ad

Analysis By: Mark Hung

Definition: 802.11ad is an in-room wireless technology standard that promises higher throughput than 802.11ac/802.11n at shorter range. It will be part of the Wi-Fi standards, and is expected to be approved in 2H12. The 802.11ad technology supports a maximum throughput of 7 Gbps in the 60GHz spectrum. It is intended to have a reach of 30 feet or less, unlike 802.11ac and previous generations of 802.11, which have a coverage radius of 300 feet or more.

Position and Adoption Speed Justification: Because of 802.11ad's high throughput and limited reach, it targets the following applications that require high data consumption and are in close proximity to each other:

- Wireless video
- Wireless docking

- Wireless storage
- Medical imaging
- In-room gaming
- Wireless projection

The first standards-compliant products, initially targeted at consumer applications, will be on the market toward the end of 2012. The key to driving the technology down the cost curve and increasing market adoption is to have a competitive market for the enabling semiconductor vendors. Given the dearth of product announcements from this group (other than from a few startup companies), it will be a few years before 802.11ad sees greater adoption, whether it is by the consumer or enterprise market.

User Advice: Designers of computing and consumer electronics devices should consider which of their platforms can best benefit from 802.11ad's target use cases. Although the range of technology suppliers is limited, eventually most of the major wireless LAN semiconductor suppliers are expected to have offerings in this space.

Business Impact:

- For mobile computing platforms, 802.11ad can reduce the number of wired ports required (e.g., HDMI, USB, eSATA and DVI) and therefore provide a better user experience and lower product cost.
- For mobile communications platforms, 802.11ad can provide higher bandwidth to enable in-room video streaming and data transfer applications.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Nitero; Silicon Image; Wilocity

802.11ac

Analysis By: Tim Zimmerman

Definition: 802.11ac is a next-generation higher-speed wireless LAN (WLAN) standard developed by the Institute of Electrical and Electronics Engineers (IEEE). The goal is to increase the throughput to at least 1 gigabit. Current proposals look at utilizing a single eight-antenna access point to service four two-antenna stations operating on 160MHz channels that provides total aggregate throughput of 6.93 Gbps. 802.11ac will operate in the 5GHz spectrum to enable backward compatibility with 802.11a/n standards and deployed solutions in the market today.

Position and Adoption Speed Justification: Targeted for conference rooms and home multimedia, future users can have multiple high-definition (HD) video streams and gaming streams active across

a house and within a room. Approval of the standard by the IEEE is targeted for late 2012. In order to achieve the throughput, this standard will use 160MHz channels, which greatly exceed the 20MHz channels that are used in 802.11g radios or even 40MHz (two 20MHz channels bonded together) that are implemented with 802.11n. This means that 802.11ac will only be implemented at 5GHz where there are enough channels available to achieve the performance. 802.11ac will also provide multiuser, multiple input-multiple output (MU-MIMO) functionality that allows multiple users to simultaneously take advantage of different radio streams.

User Advice: Consumers and enterprises should continue to monitor the progress of 802.11ac and weigh the cost-benefits against existing standards, because the scalability and current price points of 802.11n will address the vast majority of current enterprise needs. While 802.11ac will provide backward compatibility, it will dramatically affect the aggregate throughput of the coverage area as radios accommodate much slower clients. High throughput applications, such as video, can currently be addressed by 802.11n, so users need to evaluate the usage scenarios before paying any premium for 802.11ac radios. Given the immaturity of 802.11ac, no further action is necessary at this time.

Business Impact: 802.11ac will increase the top-end throughput within a coverage area that can address applications requiring large file transfers, such as computer-aided design (CAD) drawings; media unloading from digital cameras; or multiple, simultaneous HD data streams needed for telepresence or in-home entertainment. We expect that there will be an issue with the requirement to integrate eight antennas into devices such as laptops to achieve the desired throughput, because vendors are pushing back on the more than one that is needed to fully utilize the benefits of 802.11n. 802.11ac faces direct competition from 802.11n.

Benefit Rating: Low

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Broadcom; Intel; Qualcomm; Samsung

Quantum Tunneling Composite

Analysis By: Roberta Cozza

Definition: Quantum tunneling composite (QTC) is a flexible, electrically conductive material developed by British company Peratech that enables pressure switching and sensing. This is a printable polymer that changes its electrical conductivity with an applied force. The technology uses quantum tunneling to enable conductivity under pressure, which results in better pressure resolution than standard resistive techniques.

Position and Adoption Speed Justification: QTC can be used to enable pressure-sensitive touchscreens in mobile phones and new types of pressure-sensitive controls, switches and sensors for a wide range of consumer electronics (CE). Peratech has licensed its technology to Samsung-

Electro Mechanics (electronic components), QIO Systems (smart clothing and luggage) and Nissha (for touchscreens).

Currently, commercial implementations of this technology are available but still limited. It has been used in robotics, having been adopted by NASA's Robonaut, and the Massachusetts Institute of Technology recently commissioned Peratech to develop a tactile skin based on the technology — to enable robotic devices to interact by detecting touch and intensity of touch.

Nissha is planning to integrate the technology into the perimeter of handset screens and Samsung has included QTC technology in the trackpad of a Samsung qwerty handset model, where the degree of pressure applied on the keypad determines how quickly the menu scrolls. Similarly, several more immediate applications will need increased pressure applied: for example, when zooming into a Web page or for e-book readers to flip through pages of an e-book faster by applying more pressure.

Pressure sensing in controls is attractive for gaming applications, where it becomes an additional form of input. QTC can enable sensitive gesturing that can produce lines with varying degrees of thickness — which are useful for writing Asian language characters on touchscreens. Other pressure-related, touch-sensitive technology is available in the market, but the QTC material has advantages in terms of cost, flexibility and robustness.

Peratech has developed a transparent version of the QTC material called QTC Clear. This see-through layer is six to eight microns thick and features a transparency thickness similar to existing touchscreen technology. The new QTC material could be used to replace current resistive-touch technology or to enhance capacitive screens. QTC Clear has been licensed to a top touchscreen manufacturer.

User Advice: Handset vendors and CE manufacturers should investigate the opportunities enabled by pressure-sensitive QTC technology to drive further product differentiation and improvements in the user touch-interface experience.

Business Impact: QTC is a low-cost, flexible material that can be incorporated into a wide range of different products from clothing to credit cards, as well as the switches and controls of CE. Switches based on QTC material can be as thin as 75 microns, which makes this technology suitable for integration into very thin electronic designs.

QTC technology can be used on small screens and scaled to large touch surfaces. The technology can be implemented on existing display technology, such as organic light-emitting diodes and LCDs. In addition, QTC-based interfaces do not use power when there is no pressure applied, such as optical pads that draw electricity and need a constant charge.

The flexibility and low cost of the technology opens up a broad potential for applications: beyond integration into handsets and CE and into fields such as sport healthcare, automotives, robotics and industrial applications — opening up new and more refined ways of human-machine interaction based on force sensing and sensing (for details, see www.peratech.com). As an example, in May 2012 Peratech introduced an electronic "nose" based on QTC material that is able to sense the presence of volatile organic compounds and other potentially harmful toxic substances.

Benefit Rating: Transformational

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Peratech

Recommended Reading: "QTC Pressure-Sensitive Materials Enable New Consumer Interfaces"

Volumetric and Holographic Displays

Analysis By: Stephen Prentice

Definition: Volumetric displays create visual representations of objects in three dimensions, with an almost 360-degree spherical viewing angle in which the image changes as the viewer moves around. Unlike most 3D planar displays, which create the illusion of depth through visual techniques (stereoscopic or autostereoscopic), volumetric displays create lifelike images in 3D space.

Holographic displays can recreate a 3D image, but they are not true volumetric displays.

Position and Adoption Speed Justification: True volumetric displays fall into two categories: swept volume displays and static volume displays. *Swept volume displays* use the persistence of human vision to recreate volumetric images from rapidly projected 2D "slices." One approach is to project images onto a rapidly rotating mirror inside a protective enclosure (to protect the viewer from injury, should he or she attempt to touch the images). *Static volume displays* use no major moving parts within the image display volume, but rather rely on a 3D volume of active elements (volumetric picture elements, or voxels) that change color (or transparency) to create a 3D image within the display volume. Low-resolution displays may use transparent elements such as light-emitting diodes (LEDs), while some higher-resolution displays use techniques such as pulsed lasers that are directed by scanning mirrors to create balls of glowing plasma at the location of each voxel.

Holograms can be deployed as an alternative to a volumetric display, but with a more restricted viewing angle. It should be noted that the term "holographic display" is frequently (but incorrectly) applied to any image that creates an appearance of 3D. Some current theatrical and conferencing displays allow realistic images to appear out of thin air and can, with care, allow other individuals to walk "around" them. However, they are simply 21st-century implementations of the 19th-century Pepper's Ghost illusion using high-intensity projectors and Mylar display films and not true volumetric or holographic displays.

Volumetric displays have barely emerged from the laboratory, and developments remain in the very early stages, with little movement on the Hype Cycle during the past 12 months. At Siggraph 2010, Sony demonstrated its RayModeler device (a cylindrical autosteroscopic display), but this, like most others, remains firmly in the lab environment. Several companies, including InnoVision Labs and Realfiction, demonstrated 3D holographic images generated from their projectors, but none of them has been commercialized yet. The use of holographic techniques is, by far, the most advanced, but because of the intensive computing calculations required to generate the holographic image, the

cost of generating the display image is one of the hurdles toward real-life adoption. Simpler and much lower-cost solutions would be required for mass adoption, and the growing availability of 3D displays is likely to divert demand for less-specialized applications (such as marketing and retail displays) toward these less-challenging technologies.

Swept and static volumetric displays suffer from the significant dangers of rapidly moving parts or ionized particles in the vicinity of people, especially because the volumetric nature of the generated image convinces the brain that it is solid and "real" and, therefore, can be touched. In all cases, the volume of data required to generate a volumetric image is considerable — typically on the order of 1,000 times more to create a 24-bit voxel image (1,024 layers on the z-axis) than the corresponding 2D image. In all cases, the amount of CPU processing required is equally significant compared with creating a 2D image.

3D televisions create a visual impression of depth, but rely on spatially multiplexed images that deliver different views to each eye and allow the brain to reconstruct a 3D representation. They are planar displays that simulate depth through visual effects, rather than true volumetric displays that create an image in a display volume with real depth.

User Advice: Outside of specialized areas, where budgets are not significant constraints, this technology remains firmly in the lab, rather than in commercial applications. Current technologies limit the size of volumetric space that can be displayed, and the mechanical solutions create potentially dangerous, rapidly moving parts. Until alternative approaches can be delivered (which seems unlikely in the foreseeable future), volumetric displays will remain an extreme niche product. Concurrently, the rapid growth and continuing development of 3D televisions in the mainstream markets threaten to overwhelm the continuing development of volumetric and holographic displays outside of specialized markets.

Business Impact: General applications are not well-developed for business use. To date, simple applications in marketing have been deployed — usually targeted at high-end retail environments, and there are some specialized applications for geospatial imaging to enhance 2D maps, and for use in architectural rendering. However, most of these can be achieved at much lower costs using other more-commercialized technologies, such as 3D displays (which have developed rapidly during the past 12 months) and virtual worlds. Potential application areas include medical imaging, consumer entertainment and gaming, and design, but costs will need to fall dramatically for these to be viable for using true volumetric displays. With the growing availability of affordable 3D manufacturing capabilities and 3D gestural input technologies, such as Microsoft's Kinect, there is growing interest from the arts and design fields to experiment with these technologies, and volumetric displays are already being explored in this context, with numerous experimental designs for (low resolution) volumetric displays now emerging.

Benefit Rating: Low

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: InnoVision Labs; Musion Systems; Optics for Hire; Quince Imaging; Realfiction; Sony; viZoo; Zebra Imaging

Mobile Transphones

Analysis By: Monica Basso

Definition: Mobile transphones are mobile device products with an innovative and/or adaptive form factor that users can modify dynamically based on their specific contexts and needs. Some products are still at the conceptual model stage, while others are already commercially available.

Position and Adoption Speed Justification: Most smartphones accumulate a range of capabilities (the Swiss Army knife concept), without form factor optimization for most of them. As a result, people tend to adopt a combination of devices to meet their needs. For example, many use a smartphone and a media tablet.

Personalization of mobile devices is mostly about aesthetics and cosmetics — covers in fancy colors and materials, themes with images and ring tones, and accessories such as hanging items and holders. Normally, it does not concern functionality and the form factor, which are rigidly assigned to a device, depending on the target market segment. Mobile devices come with a range of capabilities and functions, but their form factors tend to be optimized on a primary function — either messaging, camera and multimedia, or Internet browsing.

Personalization can be more than that. People should get selective functions, depending on the context, for their roles and needs. Mobile devices will increasingly gain an adaptive form factor that allows personalization and optimization of use.

Today's examples of transphones include:

- Modumobile (www.modumobile.com): a touchscreen smartphone with complementary accessories that turn it into a camera, sporting equipment, and a loud speaker music player. This is the second attempt by Modumobile to the market. Initially it launched a modular, Lego-like approach, based on building blocks, to assemble and create the most appropriate form factor for a user at a given time. Because of the preliminary stage of the market, Modu went bankrupt in early 2011; its patents were bought by Google.
- Asus Padfone (http://www.asus.com/Mobile/PadFone/#overview): a 10-inch Android media tablet combined with a smartphone that can be placed into the tablet.
- CMIT (China Mobile Internet Technologies; http://www.cmitsy.com/EN/transPhone/feature.html); TransPhone, with a similar concept to the Asus product.
- Motorola Atrix with LapDock accessory: the docking accessory with its battery, screen and keyboard turn the Android smartphone Atrix into a notebook.
- Nokia Morph: a concept based on the notion that, at some point, there will be innovative materials (possibly based on nanotechnologies) to enable a flexible, foldable, stretchable design, thus enabling users to transform their mobile devices into radically different shapes.

This evolutionary process for mobile devices will develop through stages. Today's stage is based on pluggable, wired, inflexible components. The next stage is likely to be based on wireless, inflexible components, as well as wireless interconnections, such as Bluetooth and Bluetooth LE. This will enable new types of peripherals, such as intelligent jewelry that can talk to the mobile phone. Flexible is likely to start with simple flexible components talking to an inflexible handset core (for example, a flexible wrist screen talking wirelessly to more-conventional inflexible handset electronics). Before 2015, some handsets will offer separate components, such as a secondary screen and keypad. Wireless video will become a common feature, driven by the Wi-Fi Alliance's standardization efforts.

User Advice: Organizations should monitor future innovations that will drive more personalization of mobile devices. This will enable them to better meet the needs and expectations of different user groups (per demographics and gender) in their employee and client bases. Handset manufacturers not yet active in this area should investigate people's expectations and plan to deploy one or two transphone products to judge user acceptance.

Business Impact: Mobile transformer products will not significantly affect businesses until similar products become available and they become a priority for anyone involved in the mobile device ecosystem, such as mobile operators, service providers and application developers. We do not expect this market shift to happen before 2015.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Asus; Google; LG; Nokia

Recommended Reading: "Social Trends Are Influencing the Adoption of Mobile and Web Technology"

"Emerging Technology Analysis: Mobile Transphones, Mobile Device Technologies, 2009"

"Device Portability Is Subjective and Contextual"

"Future Technology: The Plastic, Flexible Gigabit Phone"

Electrofluidic and Electrowetting Displays

Analysis By: Hugues J. De La Vergne

Definition: Electrowetting displays use an electrical charge applied to a water interface to move a colored oil interface, to either show color (no voltage), or become partly transparent. Electrofluidic displays are a variation of electrowetting that use voltage to pull pigment in and out of a reservoir and spread it as a film behind the viewing substrate.

Position and Adoption Speed Justification: As new introductions to the display landscape, these technologies are at a precommercial stage. Initially, they are being proposed as a color alternative to black-and-white displays, which have dominated e-readers until the recent launch of color displays by competitors. The technology offers a low-power, compact solution that delivers a brighter and higher-contrast display (versus reflective LCD) that is fast enough to display video content at high frequencies. This feature set opens up the potential market for this technology to other consumer electronics device applications, such as status screens, keypads and larger displays. Furthermore, electrowetting leverages existing LCD fabs, meaning that displays can be produced in refurbished LCD production facilities, thus lowering the cost and risk associated with bringing a new technology to market.

Samsung acquired Liquavista in early 2011 to expand its presence in this space and to potentially expand the new technology throughout its vast display portfolio, including mobile phones and larger displays, such as televisions, which is a key reason Gartner continues to move the technology further along the Hype Cycle. Market expectations are for a product launch in 2013. Pricing will be competitive with organic light-emitting diodes and will need to approach that of LCDs in a few years' time to be adopted as a mass-market technology. Time to market will be critical, as the biggest challenge for electrowetting will be competitive technologies.

Multiple vendors offering different technologies are going after this segment. E Ink, which currently dominates the e-reader display market, has introduced color displays, while micro-electromechanical systems display vendors (such as Qualcomm) have launched products (such as mirasol) to try to expand into this space. Other vendors include:

- Electrowetting — Samsung-Liquavista, advanced display technology (adt)
- Electrofluidic technology — Gamma Dynamics

User Advice: E-reader and consumer electronics vendors should closely monitor developments in this nascent technology, especially given a suspected 2013 launch. It provides improvements over traditional e-ink by adding an element of color and support of full-motion video, as well as performance improvements that can be adapted to larger-scale displays.

Business Impact: This technology will compete with other technologies to bring an alternative for product categories that currently use e-ink displays.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Advanced Display Technology; Gamma Dynamics; Liquavista

Electrovibration

Analysis By: Roberta Cozza

Definition: Electrovibration is based on an effect in which touch receptors in the skin can be duped into perceiving texture. Electrical charges simulate the feeling of localized vibration and friction, mimicking shapes, textures and contours (such as the feel of a keyboard key or a button) on touchscreens on tablets and other mobile devices or product surfaces. No electrical charge passes through the skin as the charge is created through movement over a conductive surface. A periodic electrostatic force is created, which "deforms" the skin on the finger.

Position and Adoption Speed Justification: Many research groups are developing different types of electrovibration techniques to enhance touch display experience with tactile sensation. The most notable work comes from researchers from Disney Research in Pittsburgh, Carnegie Mellon University and the University of Paris-Sud, which used and developed an electrovibration technique called TeslaTouch, where electrovibration was used to control electrostatic friction between a touch panel (a commercial touch capacitive panel was modified from 3M) and a user's fingers.

A Finnish company, Senseg, generates tactile feedback by using a solution called E-Sense, which charges a conductive film on a touch panel to create an electric field, which causes vibration on the skin. E-Sense is based on independent tactile elements ("tixels") providing localized sensations (specifically, different textures for each finger or different area of a surface) and in this solution tactile sensations can be felt both with moving or still fingers.

Senseg's solution is not available in commercial products. However, the company is working with three top OEMs in Asia, planning to take the technology to a commercial level in late 2012. That said, the company has already postponed commercial availability once, and the end of 2012 may still be too optimistic. The first implementation will likely be on a tablet. Senseg is in talks with phone manufacturers too, but the value proposition of the technology is less appreciated on small screens and technically harder to implement. Toshiba has shown prototypes based on E-Sense. High-profile partners will be of key importance to companies such as Senseg. Challenges in adoption are also linked to user acceptance, and reliability needs to be proven in real-world deployments.

User Advice: Touch interfaces are key elements driving rich user experiences across many categories of devices. Consumer electronics, smartphones and media tablet manufacturers should explore the opportunities provided by electrovibration techniques for new forms of tactile feedback for touchscreens and other surfaces that can differentiate and enhance user experiences.

Business Impact: On-screen touch experiences are evolving and becoming more complex. Mechanical solutions are limited in their ability to differentiate and provide rich experiences based on multitouch and new gestures. Electrovibration solutions can considerably enhance the touch feedback currently delivered by mechanical vibration. This uses moving parts that wear out over time and have motors that drain battery life, generate noise and cause excessive vibration of the entire device.

Electrovibration solutions could greatly impact the way users interact with touch interfaces and screens on media tablets, smartphones, gaming handheld devices, advanced in-vehicle controls and other consumer and industrial products.

Different levels of friction can augment the manipulation of icons, files and other "dragable" items by applying simulated friction in drawing/painting applications (in the TeslaTouch experiment, various levels of friction were associated to file size when files were dragged to a folder or when items needed to be aligned).

Different textures can be applied to virtual objects and applications can be implemented for blind or visually impaired consumers (current touchscreens still largely require users to locate objects visually on the screen).

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Senseg

Recommended Reading: "Cool Vendors in Imaging and Display Devices, 2011"

"Emerging Technology Analysis: Success of Haptics for Media Tablets and Smartphones Hinges on New Application Development"

Wireless Video — 60GHz

Analysis By: Mark Hung

Definition: Wireless video is defined as any over-the-air video transmission, whether it is broadcast, multicast or unicast. This video stream can be transmitted either over the public spectrum or inside a home or enterprise using unlicensed spectrum. We are limiting the definition of this technology to wireless video transmission using the 60GHz band in a wireless LAN (WLAN) setting. Applications include video cable replacement and video display mirroring (for example, simultaneous display of the same image on two devices).

Position and Adoption Speed Justification: Wireless video technologies can be categorized along several different axes:

- Spectrum: 2.4GHz, 5GHz or 60GHz.
- Standards-based or proprietary: Wi-Fi (IEEE 802.11) is the most popular physical layer standard for WLAN.
- Network topology: Star (with a wireless router or access point in the middle) or peer-to-peer (P2P).
- Throughput: This is largely a function of the underlying physical layer standard, although the use of compression at a higher layer can increase the overall throughput.

In the 60GHz band, there were primarily two groups vying for the leadership position:

- WirelessHD: This was one of the earliest proprietary wireless video implementations, promoted by SiBEAM and several Asian consumer electronics (CE) companies. This was also the first use of the 60GHz spectrum for video transmission. With the range limitations inherent at 60GHz, this was designed primarily to be a P2P network supporting 4 to 7 Gbps of throughput.
- WiGig: Although it is not a wireless video-only standard, WiGig was formed to compete against WirelessHD, with most of the existing Wi-Fi semiconductor vendors as its members.

The two groups have since come together to combine their efforts for the 802.11ad standard. One of two next-generation 802.11 standards (the other being 802.11ac), 802.11ad is designed to support up to 7 Gbps of throughput in the 60GHz range. The 7 Gbps of throughput was the design target to provide sufficient overhead for transmitting uncompressed 1080p high-definition (HD) video at 60 frames per second (fps), which would require 3 Gbps of bandwidth. It is designed to mostly operate in the P2P mode. Whereas previously there was a lack of certainty as to how the competing 60GHz standards would be sorted out, the path to technology maturation is clearer now that they have coalesced around 802.11ad. The specification is expected to be ratified by the end of 2012, and prestandard products are already on the market today. Although the first standards-based products are expected to be available for the 2012 holiday shopping season, it will be several years before we see broader penetration of the technology in CE devices.

At the application layer, the new Wi-Fi Display standard is expected to be the transport mechanism adopted by the computing, communications and CE equipment manufacturers for P2P video streaming. This will enable these devices to interoperate more easily with each other.

User Advice: Electronic equipment manufacturers should focus on delivering standards-based products (for example, 802.11ad and Wi-Fi Display) to ensure interoperability and a better user experience, which would grow the overall market and broaden the technology's adoption.

Consumers who would like to have the ability to stream uncompressed HD video should wait until 802.11ad-based products are on the market, as they would ensure compatibility with future standards-based products.

Business Impact: Wireless video using 60GHz will have a wider impact in the consumer market rather than the enterprise market. For the former, the components in a home theater system (the audio video [AV] receiver, TV, set-top box and Blu-ray player) can all benefit from the inclusion of this technology. For the latter, the targeted markets for this technology are wireless projectors and videoconferencing equipment, although adoption in these two platforms is expected to be muted.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Apple; Broadcom; Intel; Nitero; Qualcomm Atheros; Samsung Electronics; Sony; Wilocity

Recommended Reading: "Emerging Technology Analysis: Consumer Electronics Technologies, Wireless High-Definition Multimedia Interface Cable Replacement"

Ensemble Interactions

Analysis By: Adib Carl Ghubril; Stephen Prentice

Definition: Ensemble interactions describe the syncing of a user's multiple devices to support the completion of a task in an optimal manner.

This was first demonstrated in video calls, in which the calls shifted automatically from a mobile handheld device to a large-screen TV as the user walked into a room and used gesture controls to "throw" a video from a mobile device to a larger monitor. As the complexity of ensemble interactions grows with the number of smart networked equipment, support for multi-tasking and collaborative activity will ensue.

Position and Adoption Speed Justification: Although a few demonstrations of the concept have been shown, technology that bridges the physical and digital world — to allow for multi-tasking between paper and computer work, for example — is still immature and is the subject of academic research. However, the advent of an OS platform across computing devices of various form factors and end applications, such as iOS for smartphones, tablets and TVs, raises expectations about the concept's viability. Nonetheless, user expectations about how multiple devices should collaborate in delivering an experience are undefined and uncertain, and the number of domestic devices that could participate in interactions is limited. The growth in Internet Protocol (IP)-enabled TVs, and the increasing availability of wireless networking in computing and entertainment devices, suggests that home media will be an early area of adoption of ensemble interactions. Emerging technologies (for example, wireless video interfaces) and the use of geological location technology, which triangulates the location of devices indoors using a combination of Wi-Fi GPS and cellular signals (by companies such as Navizon), will facilitate rapid shifting among display devices.

User Advice: User organizations should monitor this technology because, as it emerges, it could further complicate assumptions about what device an interaction is taking place on. This is because the device might change during the interaction. Organizations conducting business in situations in which two or more smart devices are in the same vicinity (such as when consumers congregate in retail stores) should pilot ensemble interactions implemented using communications applications.

The possibility of syncing multiple devices of many users makes ensemble interaction an enabler of collaborative work in the workplace and could also support a user's multi-tasking needs.

Business Impact: Vendors in areas such as mobile devices and consumer electronics should monitor and sponsor research into ensemble interactions. Vendors that manufacture a wide range of consumer electronics (for example, in the mobile and home entertainment markets) should explore this technology as a way to add value when consumers purchase more than one product from the same company.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Embryonic

Sample Vendors: Microsoft; Motorola

MEMS Displays

Analysis By: Tuong Huy Nguyen

Definition: Micro-electromechanical systems (MEMS) displays are ultra-low-power reflective displays in which pixel brightness and color are controlled by physical movement within a MEMS cell.

Position and Adoption Speed Justification: MEMS technology used for low-powered displays for mobile devices is still a relatively new technology, and deployment remains limited. There have been a number of different, competing display solutions available, primarily based on either transmissive or reflective technology, but the market has become more streamlined because of refocusing and consolidation.

Qualcomm's mirasol solution is currently the leading MEMS solution. It is a reflective display technology based on interferometric modulation (IMOD) technology, with MEMS structure at its core. Qualcomm's IMOD display solution operates by using spatial multiplexing mirrors to generate color using interference and the reflection of ambient light. Qualcomm's mirasol solution is a low-power, color, video-capable and sunlight-viewable display that has proven commercially available solutions. This solution improves on electronic ink by providing color and is able to show video/multimedia. Despite this, as a reflective technology, the color aesthetic is softer than that of standard displays because of the natural-light source. It produces a more "washed-out" color compared with LCDs and organic light-emitting diodes (LEDs).

Furthermore, Qualcomm has recently demonstrated an embedded front light with LEDs that's controlled by an ambient light sensor in the e-reader solution — to improve overall usability. This solution is initially positioned to challenge electronic ink in the e-reader market. It is currently used in the Hanvon c18, Kyobo eReader, Bambook Sunflower and Koobe eReader.

The Pixtronix solution combines the sequencing of microshutters and LEDs, as a backlight, to modulate the light. The technology claims lower power consumption and greater brightness, contrast, ambient viewability, and color depth for stills and video than traditional LCDs, partly because the liquid crystals, filters and polarizers are replaced with MEMS shutters. As of 2Q11, the company has developed small- and midsize-form-factor prototypes with Hitachi Display, Chimei Innolux and Samsung. As of December 2011, Pixtronix has been acquired by Qualcomm.

User Advice: Consumer electronics vendors should implement these solutions only if doing so improves the cost structure and utility of devices. They should also evaluate competing technologies, such as electrowetting displays from Samsung, when these are perfected. As a low-power solution, MEMS displays are applicable for handset vendors as green solutions, for developing markets (where access to electricity is limited), and as solutions to extend battery life (still a key concern for consumers). Consumer electronics vendors can also consider applications beyond the main screens on mobile phones, such as "status" screens found on consumer electronics products, on accessories such as headsets, or on secondary displays on phones.

Business Impact: MEMS displays in connected portable devices are expected to be a more-energy-efficient display technology than current LCD screens and to decrease costs (as they scale). This technology currently lacks scale (and requires infrastructure investment), so the benefits are offset by the added price. Moreover, it is in its early stages, with a limited number of commercially available products. With the only commercially available MEMS display solutions, Qualcomm is best-positioned for current adoption of these technology offerings. Its enhanced performance (color and video capability) over the current e-reader solutions makes it a viable solution for vendors to implement. However, adoption is further affected by its ability to meet demand.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Pixel Qi; Qualcomm; Texas Instruments

Recommended Reading: "Emerging Technology Analysis: MEMS Displays Cut Mobile Device Power Consumption"

At the Peak

Cellular to Wi-Fi Authentication

Analysis By: Tim Zimmerman

Definition: Cellular to Wi-Fi authentication provides the ability for dual-mode smartphones to move freely between cellular and Wi-Fi connectivity for voice and data applications. As part of the 802.11u standard, this multivendor and multiple physical layer authentication allows cellular connections to be transferred to Wi-Fi, as well as among multiple Wi-Fi vendors from one installation to another, whether it is a hot spot or, ultimately, within an enterprise.

Position and Adoption Speed Justification: The ratification of 802.11u, which provides the necessary functionality for internetwork communication (such as network discovery and selection), has boosted the momentum for initiatives such as the Wi-Fi Alliance's Next-Generation Hotspot or Hotspot 2.0. Initial vendor testing continues with the Wireless Broadband Alliance and the Wi-Fi Alliance. Vendor trials show the ability to authenticate; however, vendors will still need to negotiate roaming agreements and to facilitate rolling out the necessary hardware and software for the end-to-end solution for all components of the multivendor solution.

User Advice: Users should expect that, once the functionality has been agreed on by the industry, it will take time for the necessary hardware and software to be implemented. They should also expect issues with initial implementations of multiple vendor solutions in hot spots, as well as within the network infrastructure. Enterprises looking to use the technology to provide a migration strategy for roaming among Wi-Fi vendors will have more initial success, because they control the end-to-

end solution. End users may have the most success, because guests can roam to an infrastructure without the drudgery of entering codes and navigating pop-up screens.

Business Impact: The ability to seamlessly roam from cellular to Wi-Fi will be huge, as Wi-Fi continues to provide high-performance connectivity. The offloading ability will provide a solution for density-rich environments, such as stadiums, metropolitan areas or university classrooms.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Aruba Networks; AT&T; Cisco; Ruckus Wireless; Verizon

HD Voice

Analysis By: Anshul Gupta; Neha Gupta

Definition: High-definition (HD) voice is also known as wideband voice. Compared with traditional telephony voice over public switched telephone networks (PSTNs) and cellular, HD voice uses double the sampling rate, reproducing a much larger sound frequency and delivering all, or most, of the frequencies of a user's voice. HD voice's major advantage is the ability to communicate with clearer audio and have improved and more intelligible conversations over fixed line, cellular networks and voice over Internet Protocol (VoIP).

Position and Adoption Speed Justification: HD VoIP has been around since 2006 along with HD-capable IP telephone devices. Communications service providers (CSPs) also began upgrading their networks to support HD voice some time after, with the first commercial launch in 2009 by Orange Moldova. Currently, HD voice supports Global System for Mobile Communications (GSM), wideband code division multiple access (WCDMA)/Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) networks. Ericsson has successfully demonstrated HD voice on CDMA technology, but HD voice over CDMA networks is yet to be commercially launched.

CSPs' adoption of HD-capable networks is on the rise — the number of HD-capable networks rose from 16 across 15 markets in April 2011 to 39 networks across 31 markets in February 2012. Similarly, while HD-capable mobile devices are not yet a mainstream technology, more than 70 such devices were available in the market as of February 2012.

HD voice will help CSPs to differentiate their offerings. It will help in providing high-quality services not only to voice-dependent businesses such as call center services, information services and emergency services, but also to consumers as high voice quality has resulted in longer calls and improved customer satisfaction.

Even though HD voice adoption is rising, mass deployment is still many years away. The greatest commercial hurdle is that both handsets and networks have to be upgraded to deliver HD voice. This will require significant investment by CSPs in upgrading networks without any direct revenue

enhancements, while the high cost of HD voice-enabled devices will result in limited use for at least the next two to five years.

User Advice:

- CSPs should factor in the cost of upgrading infrastructure to support HD voice and HD-capable devices, keeping in mind that this may not result into direct revenue enhancement — rather, it will simply offer improved customer satisfaction and a means of differentiation.
- HD voice can be offered as a special service to voice-dependent businesses. Similarly, HD voice can be offered as premium voice service over traditional voice services to enterprises.
- Coupling HD voice with mobile devices equipped with dual noise cancellation technology will further enhance the voice quality and experience of HD voice.

Business Impact: HD voice can significantly enhance the communication experience over telephony, including fixed-line, VoIP and cellular networks. It also offers a rare opportunity for CSPs to position voice as a premium service or at least use it as a differentiator to keep competitors away.

The greatest benefit from HD voice will be longer in coming and will be in HD voice's contribution in the area of real-time communication language translation, which could aid globalization.

HD voice's greatest benefit in the home will be its contribution to using voice as a man-machine interface.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Cisco; Ericsson; HTC; Nokia; Polycom; Texas Instruments

Bluetooth 4.0

Analysis By: Mark Hung

Definition: During the past 10 years, Bluetooth has become the de facto technology for wireless point-to-point connectivity. Bluetooth 4.0 (BT4.0) is the latest revision that was introduced by the Bluetooth Special Interest Group (BT-SIG) in June 2010. It includes three specifications in one single standard:

- Classic Bluetooth: Bluetooth 2.1 + EDR (enhanced data rate).
- Bluetooth High Speed (HS): Bluetooth 3.0 + HS.
- Bluetooth Low Energy (LE): This is the new technology that is introduced in BT4.0.

Position and Adoption Speed Justification: With BT4.0, a certified device has the flexibility to pick one or more of the technologies to be considered BT4.0-compliant. For example, a sensor can adopt only the LE technology to conserve power, while a portable device can choose to implement both LE and Classic. Expect support for devices in the areas of sports and wellness, healthcare, human interface devices (for example, computer mice), and entertainment devices. This technology can be integrated into watches, wireless keyboards, and gaming and sports sensors.

The BT4.0 specification was adopted in June 2010. More and more peripheral devices are emerging that need low-bandwidth, long-lasting connectivity to other host devices. Wibree was initially designed to accomplish this purpose; however, it conflicted with the long-term goals of Bluetooth, so it smartly merged its standardization efforts with the BT-SIG. With this standard, we expect enabled devices to last as long as two years without recharging. We also expect this standard to be widely popular and to quickly increase its penetration into a wide array of devices during the next five years. BT4.0 is being incorporated into Bluetooth chips today, including CSR's BlueCore7000 and Broadcom's latest combo chip.

BT4.0 has been repositioned because product introductions around this technology have not met previous expectations.

User Advice: Bluetooth LE wireless will likely be a low-cost, mature and secure technology that can be used to eliminate cabling for peripherals. Vendors of many more products can now make the Internet part of their bill of materials.

Business Impact: More and more devices will move from stand-alone to Internet-connected, enabling many more products to move from static states to dynamic states. Problem corrections and functionality updates will be made available more quickly.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Broadcom; CSR; Marvell Technology Group; Qualcomm Atheros; Texas Instruments

Wi-Fi Direct

Analysis By: Mark Hung

Definition: Wi-Fi Direct is a technology that allows either two devices to connect in a peer-to-peer (P2P) mode or many devices to connect in a mesh topology, all using Wi-Fi as the underlying networking technology. In both cases, a Wi-Fi router, access point (AP) or repeater is not required; thus, the name for the technology: "Direct." To connect the devices together, the Wi-Fi Protected Setup (WPS) protocol is used.

Position and Adoption Speed Justification: Wi-Fi Direct was ratified as a standard in October 2010, and it is intended to challenge Bluetooth's dominance in the personal-area networking (PAN) space. It has the following advantages over Bluetooth:

- Throughput: A typical Wi-Fi connection using 802.11n has a maximum throughput of 300 Mbps. Bluetooth 3.0/4.0 + HS currently has a maximum throughput of 24 Mbps.
- Range: Wi-Fi usually has a range of 100 to 300 feet, an order of magnitude higher than Bluetooth's 30 feet.

However, Bluetooth currently has a major advantage over Wi-Fi Direct: its plethora of software profiles. When two Bluetooth devices support the same profile, it is a straightforward process of setting up the connection. Currently, the only imminent application that Wi-Fi Alliance is developing to utilize Wi-Fi Direct is Miracast (aka Wi-Fi Display), so it will be a while before it catches up to Bluetooth in terms of the richness of the set of applications.

Besides audio and video streaming, Wi-Fi Direct is also targeting low-power applications, such as sensor networks, health monitoring, fitness and PC peripherals. HP introduced a Wi-Fi Direct-enabled mouse in early 2011 that takes advantage of a PC's built-in Wi-Fi, so that Bluetooth or a proprietary 2.4GHz radio is not required. Since then, products as diverse as smartphones (HTC), tablets (Toshiba), audio headsets (Turtle Beach) digital cameras (Sony), camcorders (JVC), TVs (LG), Blu-ray players (Panasonic), printers (Samsung), and even refrigerators (Samsung) have been shipped with Wi-Fi Direct built in.

Most of the major wireless LAN semiconductor vendors, including Broadcom, Qualcomm Atheros, Texas Instruments and MediaTek, support Wi-Fi Direct in their latest product offerings. In addition, Ozmo Devices and GainSpan have chipsets in production that support Wi-Fi Direct for the low-power use cases. The latest Android release, Ice Cream Sandwich, has native support for Wi-Fi Direct in the OS.

User Advice: Given the expected prevalence of Wi-Fi Direct technology in chipsets, electronic equipment manufacturers (EEMs) should make this feature a required checklist item when evaluating vendors. Despite its promise to supplant Bluetooth, though, EEMs should consider carefully whether to use it as a complementary or replacement technology for Bluetooth, as application support for Wi-Fi Direct is still in its nascent stages.

Business Impact: With the increasing amounts of data being moved between devices, whether it is for media streaming or data synchronization, direct connection technologies such as Wi-Fi Direct will provide an improved consumer user experience with its increased throughput and ease of use. As the technology becomes more prevalent in the enabling chipsets, adoption will accelerate in consumer devices, whether they are mobile phones, media tablets, PCs or TVs.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Broadcom; GainSpan; MediaTek; Ozmo Devices; Qualcomm Atheros; Texas Instruments

Wireless Power

Analysis By: Jim Tully; Steve Ohr

Definition: A wireless power supply facilitates the charging or direct powering of electrical and electronic equipment using inductive or radio frequency (RF) energy transfer. Inductive systems are preferred for short ranges (a few centimeters) and can provide very high levels of power equaling several thousand watts or more. RF power transfer operates over longer distances (tens or hundreds of meters or more) and provides more modest levels of power (a few milliwatts or less).

Position and Adoption Speed Justification: Inductive systems are suited for PCs and the fast charging of mobile devices, while RF power is more applicable to remote sensor networks and trickle-charging of mobile phones. Combinations of both induction and RF are also used — for example, in Near Field Communication (NFC). This operates over short-to-medium range of up to 20 cm, depending on the frequency used. The NFC Forum has specified a version of the technology that operates at 13.56MHz with an operating distance up to about 4 cm.

In its most basic forms, inductive power has been in use for many years — for example, in electric toothbrushes. The focus now is on more flexible, efficient and addressable forms of the technology using resonance techniques. Most users of mobile electronic devices find battery charging to be a real annoyance. It is inconvenient, and different chargers are required for different types of equipment.

The idea of wireless charging is clearly attractive and several solutions have recently been demonstrated. For example, wireless charging schemes are being designed for use in tabletop surfaces and similar environments that will charge a mobile device when it is placed on the surface.

Several competing (and incompatible) offerings are currently available. This highlights the need for standardization before there is any chance of widespread adoption of the technology for mobile devices or PCs. An organization called Wireless Power Consortium has been addressing this issue for some time, and a specification has been published. During the past three months, another group (Alliance for Wireless Power [A4WP]) was formed, and this is likely to cause some confusion in the market. A bigger obstacle is the question of why mobile equipment makers (such as handset vendors) should be interested in this technology.

Mobile phone makers have recently agreed on a set of standards for chargers, which could set back the aspirations of wireless power vendors in this area. Prominent discussion continues about this technology, but Gartner does not see any solid evidence of a progression along the Hype Cycle. Therefore, the position is unchanged this year.

User Advice: Technology planners in organizations with many users of mobile devices should evaluate the benefits of this technology as it becomes available. Vendors of mobile devices, batteries and power infrastructure (such as chargers) should evaluate the alternatives and decide on their position in relation to this technology. Users should investigate this if they need small levels of

"trickle" charging for equipment where it is difficult or impossible to connect a physical supply — for example, sensor networks and Bluetooth low-energy devices.

Users in certain vertical organizations should also examine this technology. There may be benefit, for example, in introducing wireless-charging facilities in environments where customers spend time — such as in restaurants. This may attract customers if and when the technology starts to become popular.

Business Impact: The technology is applicable to a wide range of business and consumer situations. Some environments require mobile devices to be charged at all times, and wireless charging is particularly suited to those situations. It also offers advantages of less clutter and reduced e-waste of old chargers. Efficiency is somewhat lower than wired power, which will need to be factored into any decision.

Benefit Rating: High

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Fulton Innovation; MIT; Nokia; Powercast

Smartphone Hypervisors

Analysis By: Monica Basso

Definition: Smartphone hypervisors are thin layers of virtualization software running directly on smartphone hardware that define one or more processing environments. Initially, they have been used to reduce the number of discrete processors by defining multiple virtual processors on a single, physical die. As the technology evolves, it is increasingly used to improve the standardization, manageability and security of the application environment.

Position and Adoption Speed Justification: Business drivers for the adoption of hypervisor technology in smartphones include:

- Improving the time to market for new products and containing costs for handset manufacturers.
- Addressing the security challenges posed to networks by an increasing number of intelligent mobile devices and third-party applications for mobile operators.
- Exploiting new capabilities offered by cloud computing on mobile devices for service providers, in general.
- Enforcing IT security and management policies, particularly with bring your own device (BYOD) deployments for enterprises.
- Enabling cross-platform application portability (e.g., .NET applications to Android devices) for enterprises.

Smartphone hypervisors appeared in 2006, and first shipped in production smartphone models from HTC and Toshiba in late 2007. Development efforts increased significantly during 2007 and 2008, resulting in heightened interest from smartphone vendors and suppliers of smartphone microprocessors. VMware's acquisition of Trango Virtual Processors (November 2008), and Citrix Systems' investments and partnership with Open Kernel Labs (January 2009), validate market interest. Market developments started in 2010, with ARM's new Cortex-A class microprocessor designs with TrustZone, a standard mechanism to enforce hardware virtualization that can be exploited to create separate virtual machines to make applications more trustable. Thanks to TrustZone's capabilities in ARM's microprocessors, hardware virtualization was present in more than 50% of smartphones shipped in 2010, and will rise to 90% by the end of 2012.

Meanwhile, VMware offers Horizon Mobile, a product based on a software mobile hypervisor to enable secure BYOD deployments with Android smartphones — creating a "dual personas" phone. A virtual machine, with an Android instance plus the corporate environment, runs on the physical Android smartphone in total separation; no data or application sharing is possible among the two. Open Kernel Labs instead offers "bare-metal level" hypervisor products, embedded in chipsets' firmware by OEMs (e.g., Qualcomm). These products support separate, isolated environments below the OS, and enable even stronger containerization of corporate versus personal areas on a smartphone.

By YE13, main smartphone OSs will embed hypervisor functions and provide virtualization APIs for enhanced standardization, manageability and security of applications and data.

One issue is the processing overhead imposed on the application environment, which is already performance-constrained. Improvements in processing capability and the gradual integration of virtualization technology into smartphone processors will make hypervisor functions more appealing.

User Advice: Monitor developments in smartphone processors, as well as in mobile OSs and mobile device management platforms, for signs of when and how virtualization technology will enable stronger BYOD support with smartphones and other devices, such as media tablets. Once smartphones with hardware-assisted virtualization capabilities appear in the market, plan for the approach to become mainstream within two years.

Business Impact: Smartphone hypervisors will not deliver improvements in the manageability and security of smartphones until smartphone OS vendors also embrace and fully support them, which is unlikely to occur before YE13. Through 2012, continue to pursue established management and security initiatives.

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: ARM; Open Kernel Labs; Red Bend Software; VMware

Recommended Reading: "Smartphone Virtualization: Making Mobile Applications More Trustable"

"The Emerging Market for Smartphone Hypervisors"

"Cost Reduction Drive Will Bring Hardware Virtualization to Smartphones"

"Virtualization Will Simplify Smartphone Deployment"

"Nvidia Brings GPUs to the Cloud"

Glonass

Analysis By: Annette Zimmermann

Definition: Global Navigation Satellite System (Glonass) is a global satellite positioning system run by the Russian Ministry of Defence. It runs parallel to the U.S.'s GPS system and the Galileo system under development in Europe, and its signals can be reached by any user of a Glonass receiver globally (once all satellites are available).

Position and Adoption Speed Justification: The initial development of Glonass goes back about four decades, and the system officially began operations in 1993. During the past few years, the Russian government has invested in the modernization of the system. In December 2010, three new satellites were to be added to achieve global coverage; however, due to a calculation error the mission failed. Nevertheless, the Russian government is said to be investing $11 billion in Glonass between 2012 and 2020, and the system is now functioning globally.

During the course of 2011, more vendors have shown their support of Glonass or expanded their product coverage. Qualcomm, for example, stated that its Snapdragon S2 and S3 chipsets (when enabled) can access both the GPS and Glonass systems, and its upcoming S4 should be able to do the same. Tier 1 device vendors launched key products with dual-positioning technology in 2011, including Nokia, Apple, Motorola, Samsung and Sony. As we postulated in our earlier research, we predict that Glonass will reach mainstream adoption fairly soon because vendors plan to increase supply rapidly during the next 24 months (see "Emerging Technology Analysis: A Russian Mandate to Adopt Glonass Could Disrupt Worldwide Device Market"). As multipositioning technology will be integrated into devices by default, users will have no other choice than to take advantage of this new technology. Based on this, we have moved this technology a few positions up the Hype Cycle this year.

For the consumer, the main advantage of a Glonass/GPS combination in a handset is the increased performance — due to the availability of twice as many satellites. However, the main drawback (which has also persisted for GPS during the past few years) — severe battery drain — needs to be monitored by chipset and device vendors.

The Russian government has a lot of interest in spurring adoption of the technology and the Ministry for Transportation has announced that, in future, vehicles need to be equipped with navigation units that support Glonass. Moreover, the government had been debating, during 2011, whether to impose a requirement for device vendors to integrate Glonass chipsets into all phones to be sold in the Russian market. The date for introducing this legal requirement was the beginning of 2012; however, the Russian government distanced itself from enforcing such strict legislation in the end.

User Advice: Vendors need to deploy Glonass in mobile devices in order not to fall behind the competition that has already deployed it in high-end devices. They also need to monitor developments in Russian legislation, and the specific requirements around GIS systems in the automobile and consumer electronics industry. Glonass is strategically important to Russia, so vendors need to look out for opportunities to leverage this technology across different device types and environments (such as vehicles).

Business Impact: Even though the Russian mandate for mobile devices was not enforced at the beginning of 2012, other industries — such as the transportation and automotive sectors — will be affected by Russia's push for its own satellite system. Going forward, we will also see additional satellite systems — including Beidou and Galileo — making their services available, and respective chipsets for electronic devices are under way. Ultimately, we expect these additional systems to also be deployed by default in most devices. This trend will have an impact on the associated services and applications, because some will need adjustments in order to leverage the different satellite signals.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Apple; Motorola; Nokia; Qualcomm; u-blox; ZTE

Recommended Reading: "Emerging Technology Analysis: A Russian Mandate to Adopt Glonass Could Disrupt Worldwide Device Market"

Browser Client OS

Analysis By: Annette Jump; Michael A. Silver

Definition: The increasing focus on Web-based applications has created interest in a new form of simpler, pared-down operating systems (OSs) targeted at supporting just a browser and connection to the Internet. In browser client OSs, all applications are Web-based, and many traditional PC OS functions are missing. While they may provide simpler and lower-cost computing, they will rely on browser applications being available for most required tasks.

Position and Adoption Speed Justification: Ongoing complexity, security and support issues with client OSs, combined with the success of smaller devices, such as mini-notebooks and media tablets, have resulted in the desire for smaller, simpler OSs. Hardware configurations of those devices are significantly simpler compared with those of traditional PCs, and lighter-weight, alternative OSs, such as Apple's iOS or Google's Chrome OS or Android, may provide a better user experience. Further, Web-based applications continue to become more pervasive (see "Windows Applications Will Be Critical Through the Planning Horizon, but Lose Majority in 2012"), so a slimmer client OS will at some point be sufficient for many users to run most applications they need.

The application ecosystem and application stores will be important in determining if a browser OS will be important or compete successfully with other thinner/lighter models. However, until now, the

application ecosystem has been very limited since developers were focusing their attention and time on well-established ecosystems, such as iOS and Android, as well as the upcoming Windows 8. Microsoft's ARM-based version of Windows 8, expected in 4Q12, would seem to be Microsoft's answer to keep Windows relevant on alternative devices.

Google's Chrome OS was the first major OS announced that would support only Web browsing and browser-based applications. While Chrome OS is based on Linux, it has been reworked to support applications based only on Web standards. In 2012, a window manager was added, bringing it closer to a traditional client OS.

Browser client OSs have not had much momentum, largely due to the success of other lightweight OSs that support rich application experiences. Android on phones and iOS on phones and tablets have attracted huge developer followings, and at least for now, they seem to be more desirable to users than the browser client OS. The first Chromebook offerings were not well-received, and OEM excitement and support have weakened as OEMs divert their attention to media tablets, Ultrabooks and the upcoming launch of Windows 8 (including Windows RT, Microsoft's answer to a lighter-weight client OS).

Generally, browser client OSs tend to suffer when compared directly with traditional PC OSs because they lack much of the open extensibility, broad device support or the ability to support local rich applications. As such, consumers may be disappointed if the marketing doesn't accurately reflect the appropriate usage models. However, with the emergence of richer Web development environments (most notably, HTML5), much-richer applications can be created to satisfy user needs, and browser OSs could become more competitive within the next three to five years.

User Advice: For enterprise users:

- Understand the limitations of these OSs and their associated devices, and plan potential use accordingly.

For device vendors:

- Current browser client OSs are not suitable for the media tablet category because of a lack of multi-touch capability. In the medium term, when the touch support will be added, consider it for media tablets, too.
- In the short to medium term, explore some opportunities for devices with browser client OSs among selective education organizations or companies that look for thinner PC architectures and have some users using predominantly browser-based applications. Be conservative in your forecasts.

Business Impact: The browser client OS so far has failed to have any major impact on the consumer client market since all attention in 2011 was diverted to media tablets. It is very unlikely that devices based on browser client OSs will be any more successful in 2012 since media tablets will continue to expand and we will see more innovation with Ultrabooks and Windows RT devices. Those types of devices are expected to divert all device providers' and consumers' attention in the

next 12 to 18 months. The success of a browser client OS as an enterprise platform will likely take much longer because of application compatibility issues. Enterprises are concerned that these OSs are too immature and lack sufficient compatibility with current application requirements.

Additionally, it is unclear how OS vendors will evolve these OSs, and the potential exists for interoperability issues. To succeed, browser client OSs must gain a significant developer following, and consumers and organizations must be willing to eschew the current managed application market that has grown so popular for browser-based applications. Market share of browser OSs must grow in consumer Web books or media tablets before they will even be considered for other PC computing devices. Therefore, it is unlikely that any browser client OS will gain any meaningful market share among enterprise PC users as a PC replacement in the next three to five years.

Benefit Rating: Low

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Google

Augmented Reality

Analysis By: Tuong Huy Nguyen; CK Lu

Definition: Augmented reality (AR) is the real-time use of information in the form of text, graphics, audio and other virtual enhancements integrated with real-world objects. It is this "real world" element that differentiates AR from virtual reality. AR aims to enhance users' interaction with the environment, rather than separating them from it.

Position and Adoption Speed Justification: The maturity of a number of mobile technologies — such as GPS, digital cameras, accelerometers, digital compasses, broadband, image processing and face/object recognition software — has made AR a viable technology on mobile devices. As all these technologies converge in maturity, AR has also benefited from a growing number of open OSs (promoting native development), the increasing popularity of application stores (increasing awareness and availability of applications), and the rising availability of overlay data, such as databases, online maps and Wikipedia. The combination of these features and technologies also allows AR to be used in a number of different applications, including enhancing user interfaces (UIs), providing consumers with information and education, offering potential for marketing and advertising, and augmenting games and entertainment applications. We also believe that AR will play a role in mobile contextual interactions, and will be particularly powerful for:

- Discovering things in the vicinity
- Presenting real-world objects of potential special interest
- Showing a user where to go or what to do
- Providing additional information about an object of interest

Most current efforts in AR do not fully leverage the potential of this technology, but given the extended adoption curve, they are moving in the right direction.

There are currently two approaches with regard to the content displayed within the AR application and the underlying delivery technologies and processes: object-specific/private data and shared/public data. Marketing and branding are the most prevalent applications for AR and fall into the former category. They focus primarily on logos, product images, bar codes and quick-response codes. Examples include Tesco's price drop campaign, Yoplait gamification to promote charitable giving, and Weetabix's cereal box AR game. AR has also been trialed in sales-oriented environments, such as Macy's Backstage Pass program and Zugara's Webcam Social Shopper. Most recently, Google's Project Glass announcement increased the hype for AR but at nowhere near the level seen in 2010. We expect efforts and adoption in this type of AR to continue steadily, as brands, marketers and advertisers look to inspire engagement with their user base.

On the other hand, we expect a number of factors will slow adoption of the more advanced form of AR, which relies more on shared/public data. These issues include:

- Device requirements for AR in mobile devices are rigorous; so, although mobile services provide a great use case for this technology, it will be restricted to higher-end devices. Mobile devices have smaller screens than other consumer electronics devices such as laptops and even handheld gaming consoles, restricting the information that can be conveyed to the end user. Tablets have good potential to overcome some of these challenges — providing a good mix of portability and screen real estate. The interface (a small handheld device that needs to be held in front of you) limits use to bursts, rather than continued interaction with the real world. GPS technology also lacks the precision to provide perfect location data, but can be enhanced by hardware such as accelerometers, gyroscopes or magnetometers.
- As with other location-based services (LBSs), privacy is a potential concern and a hindrance to adoption.
- Always-on connectivity is required — data cost and battery drain are concerns of users.
- As a newer solution, there are also issues with compatibility: Competing AR browsers are using proprietary application programming interfaces and data structure, making the AR information from one vendor's browser incompatible with that of other browsers.

User Advice:

- **Communications service providers:** Examine whether AR would enhance the user experience of your existing services. Compile a list of AR developers with which you could partner, rather than building your own AR from the ground up. Provide end-to-end professional services for specific vertical markets, including schools, healthcare institutions and real estate agencies, in which AR could offer significant value. A controlled hardware and software stack from database to device will ensure a quality user experience for these groups. Educate consumers about the impact of AR on their bandwidth, to avoid being blamed for users going over their data allowance.

- **Mobile device manufacturers:** Recognize that AR provides an innovative interface for your mobile devices. Open discussions with developers about the possibility of preinstalling application clients on your devices and document how developers can access device features. Build up alliances with AR database owners and game developers to provide exclusive AR applications and services for your devices. Secure preloading agreements and examine how you could integrate AR into your UIs or OSs.
- **AR developers:** Take a close look at whether your business model is sustainable, and consider working with CSPs or device manufacturers to expand your user base; perhaps by offering white-label versions of your products. Integrate AR with existing tools, such as browsers or maps, to provide an uninterrupted user experience. Build up your own databases to provide exclusive services through AR applications. Extend your AR application as a platform that individual users and third-party providers can use to create their own content. Explore how to apply AR, through different applications and services, to improve the user experience — with the aim of predicting what information users need in different contexts.
- **Providers of search engines and other Web services:** Get into AR as an extension of your search business. AR is a natural way to display search results in many contexts.
- **Mapping vendors:** Add AR to your 3D map visualizations.
- **Early adopters:** Examine how AR can bring value to your organization and your customers by offering branded information overlays. For workers who are mobile (including factory, warehousing, maintenance, emergency response, queue-busting or medical staff), identify how AR could deliver context-specific information at the point of need or decision.
- **Brands, marketers and advertisers:** Use AR to drive increased engagement with your user base.

Business Impact: AR browsers, applications and seamless integration will be the focus of innovation and differentiation for players in the mobile device market in 2012. There are interesting branding opportunities for companies and businesses. Points of interest can be branded with a "favicon" (that is, a favorites or website icon) that appears when the point of interest is selected. Companies such as Mobilizy are offering white-label solutions that allow core Wikitude functionality to be customized. AR products such as Wikitude can lead to numerous LBS advertising opportunities.

CSPs and their brand partners can leverage AR's ability to enhance the user experience within their LBS offerings. This can provide revenue via set charges, recurring subscription fees or advertising. Handset vendors can incorporate AR to enhance UIs, and use it as a competitive differentiator in their device portfolio. The growing popularity of AR opens up a market opportunity for application developers, Web services providers and mapping vendors to provide value and content to partners in the value chain, as well as an opportunity for CSPs, handset vendors, brands and advertisers.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: GeoVector; Google; Layar; Metaio; Mobilizy; Nokia; Research In Motion; Tonchidot; Total Immersion; Zugara

Recommended Reading: "Emerging Technology Analysis: Augmented Reality Shows What Mobile Devices Can Do"

"Contextual Smartphone Applications Will Exploit Augmented Reality"

"Innovation Insight: Augmented Reality Innovations Add Business Value"

Dual Noise Cancellation

Analysis By: Anshul Gupta

Definition: Dual noise cancellation capability helps to:

- Separate background noise at the microphone, so that only the speaker's clear voice enters the communication channel and the person on the other end of the call receives the same clarity of voice.
- Reduce the amount of background noise entering the speaker's ear, by using noise-reduction technology in the headphones.

Position and Adoption Speed Justification: An electronic circuit is used to separate ambient noise from the mix of human voice and noise, so that only a pure human voice gets into the communication channel. Noise cancellation in headsets and mobile devices is achieved with two microphones: one close to the mouth to pick up the higher-intensity human voice, and the other further away to pick up ambient noise.

Bluetooth headphones — equipped with active noise cancellation features achieved by using two microphones — from Nokia, Plantronics, Samsung, UmeVoice, Sennheiser and Audio-Technica, have been available for use with mobile devices since 2010. We are now seeing dual microphones being directly integrated into mobile devices to achieve noise cancellation.

At the same time, reducing ambient noise at the listener's end can be achieved by using passive methods such as earcups designed with special material or an earbud-type headset that goes into the ear and therefore blocks the noise mechanically. There are even headsets from Bose and Sony that use active noise cancellation by generating an anti-noise sound wave of opposite polarity to that of surrounding sound. Such headsets are for use with music players in a noisy environment.

There are a few headsets available in the market that use noise cancellation technology to produce noise-free voice and reduce the level of noise from the human voice that enters the communication channel. We are seeing increasing adoption of headsets equipped with dual noise cancellation features, but the market is still at an early stage. There are clearly more use cases for such a product, because it will enable those in noisy environments to hear, and be heard, properly. This has become more important because some users tend to keep their heads away from their touch devices, leading to more disturbance and an unclear voice at the other end.

User Advice: Headsets using active noise reduction methods (with electronic circuits) are effective in reducing low-frequency sounds, but not very effective in reducing inconsistent high-frequency sounds. An additional consideration for headsets using electronic circuits is that they require a battery. This renders them bulky and power-dependent — the absence of a battery will cause the entire unit (not just the noise cancellation element) to shut down completely.

Headsets using passive (traditional) noise reduction methods are effective for reducing high-frequency inconsistent sound, but their prolonged use (especially earbud-type headsets) could cause discomfort.

Noise-cancelling, microphone-enabled headphones are very useful when the user is in a noisy environment: callers can keep a conversation relatively private by speaking quietly, while the person on the other end can still hear clearly. These headsets are premium products, priced at approximately $100, but they greatly enhance the user experience. Bluetooth headsets with dual noise cancellation are available at the lower price of about $40 (the Motorola H17, for example).

Dual noise cancellation technology would be very useful for users in noisy environments (such as call center workers and airport ground staff), as well as in public places, or at events, conferences or shows.

Business Impact: The impact of this technology is limited to users who are constantly on the move, or those based in noisy environments who spend most of their time on the phone. Products with dual noise cancellation will allow users to:

- Receive improved voice quality on mobile devices.
- Speak quietly in noisy environments, allowing them to keep their conversations private yet still be heard clearly.
- Hear the other speaker properly.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Audience; Cisco; Dell; Motorola; Nokia; Plantronics; Samsung Electronics

Mobile High-Definition Link

Analysis By: Jon Erensen

Definition: Mobile High-Definition Link (MHL) is an audio/video interface standard for directly connecting mobile phones, digital still cameras, digital camcorders and other portable consumer electronics devices to high-definition TVs (HDTVs) and displays. It is a five-pin, low-power interface capable of 1080p 60Hz quality and supporting High-bandwidth Digital Content Protection (HDCP), Consumer Electronic Control (CEC), and digital audio. It allows for a single cable to connect to the display and, at the same time, provide power for the mobile device.

Position and Adoption Speed Justification: The technology behind MHL was developed by Silicon Image. Silicon Image was also the leading company behind HDMI, which has become the standard interface for connecting high-definition (HD) audio/video components in the home. The HDMI connector was too large for small form factor mobile devices, and so MHL was developed as an alternative that would still be compatible with the installed base of devices with HDMI connections. Products with MHL were originally expected to be on the market in 2009, but that was delayed to the second half of 2010, and then delayed again to the first half of 2011. According to Silicon Image, 50 million MHL-enabled products shipped in 2011 in smartphones, tablets, digital TVs (DTVs), monitors, and home theater products and accessories. The Samsung Galaxy S II was the highest-profile MHL-enabled product and was also the first to ship.

Silicon Image, along with Nokia, Samsung, Toshiba and Sony, formed the MHL Consortium in April 2010, and they released the 1.0 specification in June 2010. As more HD content is stored on portable consumer electronics and smartphones, MHL represents a simple way to display this content on a larger screen. Some companies have tried to use wireless technologies, mostly Wi-Fi, to display content stored on a mobile device on a larger display, but the quality, ease of setup and the lack of a standard to perform this task will slow adoption. This situation is expected to change with Wi-Fi Direct and proprietary implementations, including Apple's AirPlay, which are slowly gaining traction.

In the interim, MHL has an opportunity to become a wired option for connecting mobile devices to HD displays. The main wired competition for MHL will come from mini-HDMI, which has become the standard wired connection, although it requires a larger, separate connection and is not designed to provide power. MHL can be converted to HDMI-compliant signals for connection to a DTV using an active cable or dock with a conversion chip. MHL can utilize established connectors — mostly mini-USB — that are currently found in many mobile phones and portable consumer electronics products. Using existing connectors is cost-effective, saves space for small form factors, and allows consumers to get more functionality from a single connector. For this to work, it needs to be a standard port. If it is altered, it will likely require an adapter, as is the case with the Galaxy S III. Also, in order to be powered, the phone will need an MHL port to connect to, but the number of MHL-enabled products is still limited. The repeated delays in introducing MHL-equipped devices have put the success of the standard in jeopardy, especially as wireless alternatives have gained more traction.

User Advice: Device manufacturers should closely follow the MHL Consortium's progress in promoting the MHL standard and be prepared to use this as a simple, wired connection for media-centric portable devices. It will be an important alternative to wireless solutions.

Business Impact: The impact of widespread MHL adoption is that users will be able to rely on their smartphone or tablet in more situations and not need to travel with heavier notebook PCs. Consumers will be able to share content stored and captured on their mobile phone on larger displays.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Nokia; Samsung Electronics; Silicon Image; Sony; Toshiba

Solar Power Mobile Devices

Analysis By: Annette Zimmermann

Definition: A phone equipped with solar cells that converts sunlight into electrical power, reducing or removing the need to charge the device from an electrical power source.

Position and Adoption Speed Justification: The idea of solar-powered mobile devices has been around for some years, but has never seen any significant uptake. Solar-powered mobile chargers have been on the market for years, serving the need of frequent travelers. Prototypes and developments were announced some years ago by the Chinese vendor High-Tech Wealth, Japanese firm NTT Docomo and the German research institute, Fraunhofer-Gesellschaft. In 2009, Samsung, LG and ZTE started selling new solar-powered devices. The main selling point has been for users in emerging markets. The GSM Association (GSMA) estimated that around 500 million mobile users in emerging markets do not have regular access to electricity and would benefit from alternative charging solutions, such as solar devices, solar chargers or operators' solar-powered charging stations that have recently emerged. Tier 1 vendors including Samsung, LG and ZTE sell low-end devices in several African, Southeast Asian and Latin American countries.

Since about mid-2011 it seems that Tier 1 vendors have lost interest in this technology — the number of new product launches has diminished significantly, of which Samsung had been one of the most active vendors. Only niche players, such as Intivation, which launched the Umeox Apollo at Mobile World Congress 2011, an Android-based phone with a solar panel, seem to still be active. In mature markets, Samsung used to launch high-end devices with solar panels on the battery cover, labeling them as "green," a strategy that in Gartner's view was debatable due to the solar cell's rather long return on energy investment time, or charge back time. We believe that Samsung has realized that consumers in mature markets do not really see the value in this technology, not even in the context of environmental preservation. It is an expensive technology to adopt (see barriers to adoption below), and it has not really brought the desired return on investment to the vendor (or the user).

The general view of the industry is that it takes about 18 months to two years of energy consumption to equal the amount of energy consumption used in manufacturing the solar cell. This value depends on the size of the cells as well as the location (for example, those exposed to bright sunlight most of the time as in the Sahara, compared with a location in Scandinavia). The time scale also assumes constant exposure to sunlight, so the time required for solar cells on mobile phones to reach their potential is on average much longer (than 18 months to two years). This suggests that the actual environmental benefit sets in only when users keep their devices for longer than 18 months to two years. This is less of a concern in emerging markets where device replacement cycles last longer than 24 months, but in developed markets users sometimes replace their devices after 12 to 18 months.

Apart from the Tier 1 device vendors (which have lost interest now), startup company Intivation is investing in this market. Intivation provides a photovoltaic (PV) cell technology platform based on a single solar cell and boost converter — SunBoost3 — that powers mobile devices with sunlight. The strength of this technology lies in its capability to allow charging in indoor and low-light conditions. Devices with Intivation's technology have been deployed in 30 countries in less than two years — primarily Africa but also India, China and Germany. Device vendors that are using Intivation's technology include ZTE, Sharp and Umeox.

Barriers to adoption:

- Power efficiency: These PV solar cells take a significant amount of time to charge the phone for even a short phone call.
- Bill of materials (BOM) cost: PV solar cells such as these may add between $3 and $9 to the BOM for a mobile phone, depending on the size, technology, quality and power output of the solar cells involved. This represents a significant fraction of the cost for a phone, without a clear market demand for it at present. For comparison: a 3.5-inch capacitive touchscreen currently costs between $15 and $20, while a GPS chip costs less than $2.
- Usage patterns: The most common user habit — carrying a phone in one's pocket — causes the main problem and minimizes the chance to make full use (if any) of solar charging.

Given that this technology has lost some momentum and support from Tier 1 vendors and we don't expect any Tier 1 vendors to focus on this in the near-term, the technology has maintained the same position on the Hype Cycle as last year.

User Advice: **Device vendors:**

- Gartner advises against marketing campaigns that highlight the positive environmental impact of high-end solar devices, particularly those to be used in developed markets. This is in light of the fact that a small solar panel has a return-on-energy time span that exceeds by far the average life of a phone in developed markets. Using recycled material and offering efficient chargers are much better ways to put an environmental strategy into practice.
- When offering solar devices, consider incorporating technologies that help to preserve battery life. Examples are micro-electromechanical systems (MEMs) and organic light-emitting diode (OLED) screens.
- When offering such products in emerging markets it is recommended to focus on low-cost phones. This meets the needs of the main target audience and the chances are higher that the solar panel will be effective, as opposed to in high-end devices with high energy consuming features.

Operators in emerging markets. Analyze the business case for offering solar devices as it could offer additional revenue streams due to potential higher service usage.

Battery companies. Check now what new requirements there are for batteries when used in conjunction with solar panels, and work closely with handset vendors.

Business Impact: The impact is limited to: (1) users in emerging markets with infrequent access to electricity, as the technology works best in countries with high availability of solar energy. However, price could be an issue; (2) frequent (business) travelers, as the technology offers convenience for these users; and (3) engineers, miners, developers, people in nongovernmental organizations and military personnel, who spend a significant amount of time in rural locations without access to electricity.

Benefit Rating: Low

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: Intivation; LG; Samsung; Sharp; ZTE

Recommended Reading: "Cool Vendors in Consumer Devices, 2012"

Sliding Into the Trough

Head-Mounted Displays

Analysis By: Brian Blau

Definition: Head-mounted displays (HMDs) are small displays or projection technology integrated into eyeglasses or mounted on a helmet. Heads-up displays (HUDs) are a type of HMD that does not block the user's vision, but superimposes the image on the user's view of the real world. An emerging form of HUD is one where the display is either integrated into contact lenses or else "painted" directly onto the user's retina. In all cases the user perceives the virtual image to be at an ideal viewing distance even though no screen is present.

Position and Adoption Speed Justification: Commonly deployed in military applications (such as driver, flight and combat training), the technology is well-developed but has yet to find a vehicle for broad adoption in the enterprise and consumer markets. Several HMDs have targeted the gaming and video markets with little success. The availability of stylish, consumer-grade video eyeglasses may eventually drive adoption; for example, as a peripheral device for private video viewing on planes. However, recent attempts at this market have failed to take hold, such as Myvu's Crystal Personal Media Viewer, despite it being sold relatively broadly in gadget stores and enjoying considerable press in 2009.

In 2012, Google previewed the Project Glass research initiative, a wearable computing device that includes a wrap-around pair of glasses with a see-through display. While the project includes an HUD, it also incorporates an intelligent system designed to augment your view with information typically found in your smartphone.

Despite Google's augmented reality project, and due to a lack of new HMD products, renewed interest in the broader consumer market, and significant user experience barriers, we expect continuing disillusionment for HMD technology during the next few years. On the positive side, the

growing popularity of augmented reality on mobile devices may provide some crossover impetus for similar functionality on a head-mounted form factor (for example, from Vuzix). Further improvements will focus on resolution, field of view, battery life, comfort and cost — all of which are constraining current adoption.

User Advice: Consider HMDs for wearable or augmented reality applications where the user's hands are occupied with a task or where the user needs to be moving while accessing information — for example, to review work instructions, schematics or customer data. Content and service providers should monitor Project Glass from Google and be prepared to plan for integration, but must balance out factors such as user experience, being first to market, and finding business models that support product and market growth.

Business Impact: Outside of simple video viewing, impact areas will be in vertical markets where combining key information with real-world views improves safety and productivity (medical or engineering, for example). Long-term uses will be in entertainment, gaming and mobile communication, as well as in computing devices, simulation and training.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Google; MicroVision; Rockwell Collins; Sensics; Vuzix

NFC

Analysis By: Mark Hung

Definition: Near Field Communication (NFC) is a wireless technology that enables a variety of contactless applications, such as payments, information retrieval, mobile marketing and device pairing. It has an operating range of 10 cm or less using the 13.56MHz frequency band. Three user modes are defined for NFC operation:

- Card emulation
- Tag reading
- Peer-to-peer (P2P)

These modes are based on several ISO/IEC standards, including ISO14443 A/B, ISO15693 and ISO18092. The NFC Forum is the industry group that specifies the use of these standards.

Position and Adoption Speed Justification: For the past decade, NFC has been a technology looking for a solution. Originally intended as the foundation for next-generation payment systems using smart cards, it never caught on due to the lack of a compelling value proposition. As mobile phones became more prevalent globally in the mid-2000s, Nokia tried to push the technology in this new platform. However, the ROI was still unclear for financial institutions, payment processors,

credit card issuers and most importantly, merchants. Nokia introduced it on only one feature phone, the 6131.

In November 2010, Google breathed new life into NFC by embedding it into its latest smartphone, the Google Nexus S. This became the first widely available smartphone with built-in NFC. During the next several months, Google enhanced the Android OS to eventually support all three modes specified by the NFC Forum — another first. During 1H11, all the major smartphone OS vendors, with the notable exception of Apple, announced support for NFC by the end of 2011:

- Android: Samsung, HTC, LG, ZTE, Huawei
- RIM: BlackBerry Bold and Curve
- Symbian: Nokia
- Windows Phone 7: Nokia

By embedding NFC into the smartphone platform, the hardware and software companies hope to move beyond payments and provide the developer community with another tool to foster innovative applications, such as:

- Gaming: Rovio has introduced a version of "Angry Birds" that will allow NFC-enabled phones to unlock unique levels of play.
- Social networking: Poken has pioneered the use of NFC to allow people to not only exchange contact information, but also profiles from various social networking sites, to build out their social network. This network can then be used to share coupons, offers and virtual goods.
- Information retrieval: NFC tags can provide a richer experience at museums by providing the user with more information about the display. Additional use cases include real-time schedule information at transit stops and smart advertising.
- Device pairing: NFC can serve as the setup channel for connecting two devices together, such as a Bluetooth headset with a phone or a wireless printer with a PC.
- Access control: Instead of providing a guest with a key card, a hotel can download the key to the guest's handset at check-in and deactivate it upon check-out. Similarly, enterprises can use NFC-based devices to replace existing badges for physical access control.
- Location-based services: Foursquare has started an NFC pilot by installing NFC tags at local merchants to facilitate the check-in process.

Progress has also been made in the NFC payment segment. ISIS, a consortium of mobile carriers in the United States that includes Verizon Wireless, AT&T and T-Mobile, decided to drop its initial plans for forming a new payment network and to instead work cooperatively with the existing financial institutions. Google, on the other hand, introduced the Google Wallet, which has the support of some of the leading players in the mobile payment ecosystem, including Citi, MasterCard, First Data and Sprint. Most notably, Google is not sharing in the transaction fee structure that's been established between the existing players, opting instead to monetize this platform via offers and advertising. The Google Offers product that was introduced with Google Wallet allows users to transfer online coupons into the wallet to be used in brick-and-mortar stores.

Similar progress has been made in the U.K. (Orange UK/Barclaycard), France (expansion of the Nice Cityzi trials to other cities), Korea (KT), and Japan (FeliCa going dual mode with support for NFC).

NFC payment, however, with multiple parties that have differing interests and agendas, remains the most complex and time-consuming application to implement. For the next few years, growth of NFC will be primarily in smartphones and the surrounding digital ecosystem devices, such as tablets, PCs, printers and TVs. For NFC to take off in payments, a compelling case must be made for the merchants and the financial ecosystem to invest in the necessary infrastructure.

User Advice:

- Electronic equipment manufacturers should carefully examine NFC's possible use cases and determine which of their mobile, computing, communications, and consumer electronics devices can benefit from its inclusion.
- Software developers should explore the combination of NFC with a smartphone's other capabilities to bring about innovative applications to bridge the online and physical worlds.
- Wireless connectivity semiconductor vendors should re-examine their product road map and decide how to offer this capability to their customers, whether through a partnership, acquisition or organic development. This will become a checkbox item for connectivity on smartphones within two to three years.

Business Impact: NFC can bring about unrealized applications by embedding identity into a multifunction computing and communications platform, such as the smartphone. Although this will have the most impact at the consumer level at first, it may eventually have a strong influence on context-aware computing and security control in many different industries and enterprises.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Broadcom; Google; Inside Secure; Nokia; NXP Semiconductors; Research In Motion (RIM); Samsung

Mobile WLAN Access Points

Analysis By: Jon Erensen; David A. Willis

Definition: Mobile WLAN access points allow WLAN-enabled devices to connect to the Internet by using a 3G/4G cellular connection. The capability can be part of a stand-alone mobile access point, such as a MiFi device, or a feature of an existing portable device, most likely a smartphone. The mobile WLAN access point is recognized by the WLAN-enabled device as a wireless hot spot. Compared with a typical WLAN access point, the difference is that it uses a 3G/4G cellular connection instead of a wired broadband connection to the Internet.

Position and Adoption Speed Justification: Mobile WLAN access points were first introduced in the U.S. in mid-2009 by Novatel Wireless and have expanded to include many different carriers and regions. In addition to the dedicated mobile WLAN access points, high-end smartphones are increasingly incorporating this technology as a feature, and that has the potential to significantly increase adoption. Mobile WLAN access points can be used as an alternative to accessing the Internet through a digital cellular connection. They allow an end user to pay for one digital cellular contract and then connect multiple devices using Wi-Fi, instead of paying for a digital cellular connection for each device individually. This can save end users money by limiting the number of wireless data plans they need to pay for, and it can also allow them to forgo an embedded digital cellular connection and rely on Wi-Fi only. This can amount to significant savings in the cost of hardware. For example, an iPad with a 3G connection costs $129 more than a Wi-Fi-only version. This is especially important as the number of potential devices with digital cellular connections increases. Notebook PCs, media tablets, video game handheld devices and e-book readers are all adding digital cellular connections, but they are not standard features. But there are potential hurdles ahead. With carriers switching to metered pricing, this could be expensive, depending on the number of devices a user connects and the amount of data used. Using a smartphone-based mobile WLAN access point solution can drain the smartphone battery. With dedicated hardware such as the MiFi, the battery life is also limited, although you can charge most dedicated devices through a USB port if you are using it with a notebook PC. Carriers are also expected to increasingly offer shared data plans, which, if priced aggressively, could limit the need to use a mobile WLAN access point.

User Advice: Device manufacturers should consider embedding mobile WLAN access point technology into products, including smartphones and media tablets with cellular connections. We expect this technology to become a common feature on high-end devices as handset vendors and wireless carriers look to differentiate their products and increase average revenue per user.

For corporate users and consumers that have the need or desire to connect multiple portable electronics to the Internet where a fixed access point is not available, a mobile WLAN access point has the potential to be more cost-effective than paying for individual connections. It also can lower the cost of the device itself, because a user would require WLAN but not a 3G/4G cellular or WiMAX connection. Users also need to understand the data plans and pricing for mobile WLAN access points to avoid excessive fees.

End users should keep an eye on shared data plans introduced by carriers as these plans may prove to be a competitive alternative to mobile WLAN access points.

Business Impact: Mobile WLAN access points have the potential to lower data fees for users that use multiple devices, limit compatibility issues, and lower the hardware cost by requiring only WLAN in devices rather than 3G/4G cellular or WiMAX connections. Adoption of mobile WLAN access points will give users flexibility in accessing the Internet from multiple devices without having to pay for an Internet connection for each individual device.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Apple; Cradlepoint; HTC; Huawei; LG; Motorola; Novatel Wireless; Palm; Samsung Electronics; Sierra Wireless; ZTE

Recommended Reading: "Competitive Landscape: Worldwide Cellular Modem Market"

"Forecast Analysis: Cellular Modems, Worldwide, 2009-2016, 1Q12 Update"

Gesture Control

Analysis By: Stephen Prentice

Definition: Gesture control is the ability to recognize and interpret movements of the human body in order to interact with and control a computer system without direct physical contact. The term "natural user interface" is becoming commonly used to describe these interface systems, reflecting the general lack of any intermediate devices between the user and the system.

Position and Adoption Speed Justification: The initial commercial phase of gesture control began with handheld devices that detect motion, such as the Nintendo Wii's 3D controller, as well as 3D mice and high-end mobile phones with accelerometers. We now recognize these as a distinct subcategory — "assisted gesture control" — which makes use of additional physical objects (such as gloves and inertial sensors) to enhance the interpretation and/or resolution of detectable movements.

The overall technology is now advancing rapidly, as camera-based systems (which usually obviate the need for assistive devices) have entered the market strongly. The most visible and easily accessible is the Microsoft Kinect gaming controller, and the decision by Microsoft to release the Kinect for Windows SDK provided a huge boost for the platform, opening the way to a wide range of potential applications in multiple areas, including business and healthcare, as well as gaming. Microsoft Kinect combines camera-based, full-body gesture and movement recognition with face and voice recognition to provide a rich interface. Such composite interfaces are likely to become more commonplace, especially in the consumer environment. Indeed, a sustained period of competitive feature enhancement looks likely among Nintendo, Sony and Microsoft, leading to ever-improving capabilities, including improved facial recognition and greater resolution. The inclusion of these capabilities on increasingly powerful handheld devices and mobile platforms offers interesting possibilities, which will drive further developments in areas such as augmented reality. Most recently, Microsoft Research revealed an alternative sensing approach using high-frequency sound waves and detecting the Doppler effect, which appears to work satisfactorily over short distances and may open up new options for desktop and handheld devices. The announcement of a new low-cost device from Leap Motion promising submillimeter discrimination within a limited (desktop-sized) zone is likely to drive further possibilities for desktop devices.

A more limited subset of gesture recognition and control (in 2D only) has become common with the recent development of multitouch interfaces (such as the Apple iPhone or Microsoft Surface), in which multiple finger touches — pinch and squeeze, flicks, and swipe-type gestures — are used to provide a richer and more intuitive touch-based interface.

Gesture recognition involves the effective use of a variety of input devices (to provide either 2D movements or full 3D information) and considerable data processing — to recreate wire frame models of body positions and vector-based dynamics (for speed and direction of movement), followed by the interpretation of these gestures into meaningful commands to an application. The conceptual design of a user interface based on gestures is a considerable task — both from a technical standpoint and from a cultural and anthropological perspective, especially in a global market where cultural sensitivity must be taken into account. Nevertheless, this is an area that is attracting considerable interest from researchers, and the ability to create mashup-style interfaces from readily available components makes experimentation accessible. The SixthSense project at MIT is a good example, linking the use of gesture recognition with augmented reality to explore a new generation of interactions. Business applications are already starting to emerge; a good example being the use of Kinect to track and record shopper behavior to provide retail analytics (see www.shopperception.com); although this does not directly involve "gestures," it exploits the ability to recognize and interpret body movements and is more accurately in the field of video analytics.

While the benefits of gestural interfaces in gaming applications are clear, the creation of intuitive and logical natural user interfaces for business applications will take several years. The logical mapping of intuitive and standardized gestures into meaningful commands with which to control a business application is a significant challenge. The rapid adoption of media tablet devices and the continuing growth of smartphones have significantly increased the use of multitouch-based interfaces in recent years, and this is in no small part due to the widely accepted "standard" touch and multitouch actions such as pinch, rotate and flick. The establishment of well-understood standard touch gestures is now spilling over to larger devices, and a number of developers are creating solutions designed for a variety of platforms from handheld devices to large wall-mounted displays, although a consistent set of standard gestures has yet to emerge. For example, business-oriented solutions (such as those from iNUI Studio) are already appearing and are targeted at specific vertical business markets, using camera-based gesture recognition as part of portfolios of natural user interface solutions for handheld devices and wall-mounted displays. We anticipate the following:

- The growing availability of devices and the rapidly increasing accuracy, combined with the growing number of devices requiring control, many of which are becoming embedded into the fabric of our environment, means that the traditional control paradigms are no longer appropriate. Gesture control allows control from the distant "lean-back zone" to the immediate "lean-in zone" and is looking increasingly significant as a primary interaction paradigm with the ability to transform the way humans interact with computers. We have therefore increased the benefit rating from moderate to transformational.
- With mainstream products in the gaming market now well-established, gesture control is moving quickly through the Hype Cycle, and the growing availability of options advances it from "emerging" to "adolescent" in terms of maturity.
- While mainstream adoption in gaming is happening quickly, the time to plateau in the enterprise space will be longer.

User Advice: Gesture control is just one element of a collection of technologies (including voice recognition, location awareness, 3D displays and augmented reality) that combine well to reinvent human-computer interaction. Enterprises should:

- Evaluate handheld and camera-based gesture recognition for potential business applications involving controlling screen displays from a distance (the "lean-back" operating zone). Consider business-oriented toolkits, as well as those targeted at the gaming sector.
- Evaluate the new generation of desktop-oriented devices and consider what role they may play in the "lean-in" operating zone.
- Consider how these may be combined with location-based information and augmented-reality displays.
- Look carefully at developments in the gaming sector; these will form the basis for a variety of early prototypes for business applications.

Even the simplest use of gesture, movement or touch can be introduced to existing products (especially in the handheld space) to enhance the user experience. Even almost-novelty items (such as the Kymera Magic Wand, which can control devices at a distance with learned infrared commands — www.thewandcompany.com) can create engaging user experiences in an otherwise keyboard-dominated world.

Business Impact: The primary application for gestural interfaces at present remains the gaming and home entertainment market. However, the potential of hands-free control of devices and the ability for several people to interact with large datasets are opening up a wide range of business applications — including data visualization and analytics, design, retail, teaching, and medical investigation and therapy.

As computing power moves from a single device to an "on-demand" resource, the ability to interact and control without physical contact frees the user and opens up a range of intuitive interaction opportunities, including the ability to control devices and large screens from a distance. For smaller desktop and handheld devices, the ability to control the device without physical contact opens up interesting possibilities in healthcare applications (where physical contact may result in transfer of bacterial material) as well as the design aesthetics of avoiding unsightly finger marks on touch-based devices.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: eyeSight; GestureTek; Gyration; iNUI Studio; Leap Motion; Microsoft; Nintendo; Oblong; PrimeSense; SoftKinetic; Sony

Software-Defined Radio

Analysis By: Jim Tully; Sylvain Fabre

Definition: Software-defined radio (SDR) provides software control of significant parts of a wireless function rather than through traditional hardware control. This allows devices to switch dynamically between protocols and frequencies under software control. SDR is most attractive where standards are changing and uncertain, or where multiple standards are required. Smart antennas are an important part of SDR and are typically implemented as an array of elements with programmable characteristics such as field width, frequency and waveform shape.

Position and Adoption Speed Justification: SDR has the potential to reduce device cost and hardware complexity, as less radio hardware is required to support many protocols. SDR could also enable advanced concepts such as cognitive radio, in which devices dynamically negotiate protocol and spectrum use depending on their needs and the needs of other devices in the vicinity.

The ultimate goal is that the radio frequency and baseband components of the wireless device are fully programmable and can switch frequencies and protocols in milliseconds. The critical element of SDR is designing a programmable radio that operates over a broad range of frequencies. This is as challenging, if not more challenging, than implementing the baseband function.

While SDR technology has already been used in cellular base stations, it has had little impact on mobile devices. Chips implementing partial SDR solutions are available for use in some mobile devices, such as laptop data cards and for selected components of wireless systems, such as baseband processors. SDR is likely to be more attractive for use on high-end devices, such as smartphones, which must support many different wireless standards and protocols.

Practical SDR implementations will rely on relatively high-performance digital signal processor (DSP) technology. Current DSP-based processors, with the appropriate clock rate, consume too much power for most handsets, but significant developments are being made in power reduction. However, it will take many years before SDR is used on a wide range of mobile devices. One early example of a primarily SDR-based baseband chip from Nvidia/Icera will be shipping in a commercial mobile phone this year (ZTE's Mimosa X).

User Advice: Communications equipment vendors should already be seriously evaluating this technology. In the long term, SDR has the potential to make mobile devices less expensive and more flexible.

Business Impact: SDR has the potential to reduce the cost of mobile devices and bring them to market more rapidly by lowering production costs. SDR enables multimode, multiband and/or multifunctional wireless devices that can be modified using software upgrades performed in the field, or over the air.

Manufacturers of mobile devices that include multiple radios should pilot SDR technology as it becomes available and adopt it when the economic case is proven when the performance and power consumption of SDR is acceptable.

Benefit Rating: Transformational

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: BitWave Semiconductor; IMEC; mimoOn; Nvidia; Sandbridge Technologies; Silicon Hive; Tensilica; Vanu

Recommended Reading: "Magic Quadrant for LTE Network Infrastructure"

"Forecast: Mobile Data Traffic and Revenue, Worldwide, 2010-2015"

"Emerging Technology Analysis: Self-Organizing Networks, Hype Cycle for Wireless Networking Infrastructure"

"Dataquest Insight: IPR Issues Could Delay Growth in the Long Term Evolution Market"

Indoor Positioning

Analysis By: Annette Zimmermann

Definition: Indoor positioning uses information about the indoor location of mobile devices — derived from cellular networks, Wi-Fi access points (APs) or other technologies — to deliver a service.

Position and Adoption Speed Justification: Indoor positioning has gained traction in enterprise environments for locating (employee) equipment and parts and goods. Although there are many use cases for indoor positioning on mobile devices in the consumer market, uptake has been very limited until now, with few test runs and even fewer commercial launches. The trade-offs between accuracy, costs and coverage of the different positioning technologies have been the main challenges to the uptake of indoor positioning in the consumer space. In addition, as with outdoor location-based services, marketers need to be convinced that there is user acceptance and demand (as evident from various Gartner user surveys) for location-based advertising.

Consumer location services have been focused mainly on outside areas. However, there are plenty of use cases inside buildings, such as when a user wants to walk from A to B (rather than driving) and, before leaving his or her current location, sets up the navigation tool or checks on interesting places that are close to destination B. Other scenarios that are even more interesting are shopping malls, airports, train stations, museums, exhibitions, conferences, night clubs and other large crowded places where people need to find their way around or there is the possibility of providing them with a service. Brands, retailers and marketers could use indoor positioning as a tool to present context-enriched offerings, information and services to users.

The ultimate solution will be a combination of several technologies to provide indoor and outdoor positioning. Wi-Fi is most likely to emerge as the mainstream indoor positioning technology in the consumer space, due to its high accuracy and the ubiquity of Wi-Fi APs. Wi-Fi chips are incorporated mainly in smartphones, but devices with open OSs are moving quickly into lower price

segments. In 2013, 792 million smartphones will be purchased, accounting for more than a third of all mobile devices sold.

The main indoor positioning technologies available include Bluetooth, RFID, Cell ID, Wi-Fi, Uplink Time Difference of Arrival (U-TDOA), and GPS repeater extended with algorithms such as dead reckoning. We have described their advantages and disadvantages and how they work in specific reports (see, for example, "Location Technologies: Sensors, Tags, Beacons and More" and "Location Technologies: Wi-Fi, Satellite and Cellular").

Innovation is driven by a number of larger players, as well as by startups. Gartner has identified more than 40 different companies offering indoor positioning technology that are competing in this market. In 1Q11, Navteq (a wholly owned subsidiary of Nokia) announced its own indoor map product, called Destination Maps (using Point Inside maps). Qualcomm and Cisco have also raised their profile by testing their own indoor technology at Mobile World Congress this year. Also, Google has created indoor maps of larger venues such as shopping malls and airports, adding imaging of the shops' interiors where possible. In trying to find a solution for issues with precise positioning, the vendor recently launched an app — venue owners who have uploaded their floor plans to Google's mapping service use this app to provide Google with feedback about how accurate its predictions are for their locations.

Startup companies Point Inside and Micello have been building up a database of indoor maps of all major malls and airports in the U.S., which can be licensed to airlines and retailers that want to develop their own customer experience on top. A large U.S. retailer, Meijer, is using Point Inside's technology to let its customers search for and find the location of products, receive detailed product information, find out about sales and location-based promotions, and download highly personalized discounts and coupons.

The market has become even more competitive over the past year, with players such as Walkbase, Sensewhere and Pole Star intending to license their proprietary solutions. Pole Star brought its first commercial product to market in 2009 and has since expanded to several continents, providing both consumer-facing and enterprise solutions. Apps based on this solution, such as My Way Aeroport de Paris, can be downloaded from Google Play. Once the solutions are installed on the mobile device a connection to a server is not necessary, as the position is calculated directly on the device. This means very low overhead costs for the user as no data is required and enables real-time positioning without any latency due to server connection.

We have moved this technology forward slightly on the Hype Cycle. We have seen more companies entering the space, some launching commercial products and some have increased their revenue. However, given that we are not seeing any stable business models yet, nor any larger player taking over the whole space, we have not yet moved the technology to post-trough.

Barriers to adoption:

- We are currently seeing a highly fragmented market with different vendors trying to find partnerships with larger brands, real estate owners, airports and retailers to commercialize their solutions and to drive adoption. That creates a patchwork of services and applications that are currently bound to certain locations, making them hard to scale and thus limiting user uptake.

- Clearly, not everyone can win this race for scalable services as the technology of some of the vendors in this space is hard to scale to begin with. This is related to the fact that some of the vendors have built up large databases of Wi-Fi access points or created maps that are necessary for the mobile positioning to work. This data is expensive to collect and maintain but quickly becomes a commodity.
- With the release of iOS5, Apple has made the function for searching for available Wi-Fi networks in the surrounding area a private API, and so developers developing for this platform need to find work-arounds in order to comply with Apple's developer rules. A few Wi-Fi-scanning applications have already been removed from the App Store by Apple, as they were found to be using its private API.

User Advice: Device vendors should monitor developments in indoor positioning technology and recognize that it will make your existing location products much more compelling when the move indoors can be made.

Read Gartner's user survey results ("User Survey Analysis: Enhancing the Effectiveness of Communications Service Providers' Advertising Initiatives"), which clearly show users' interest in location advertising, information and coupons.

Business Impact: The largest impact will be in the consumer space. As context services have become a key differentiator, the use of those services indoors will close an important gap in the current service landscape. Many key applications such as friend finder/social networks and location search should be able to be used just as well inside as outside. Addressing this point will make a solution much more attractive to users as, in the end, it will create opportunities for more frequent use.

There will also be a large impact on the retail industry. Technology providers that can provide solutions with targeted offers and analytical data about the consumer at a low cost will make early wins in this industry. There are solutions, such as the one from shopkick, that provide a relatively low-cost solution for individual retailers with very targeted offers.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Micello; Nokia; Point Inside; Polaris Wireless; Pole Star; Sensewhere; Skyhook

Recommended Reading: "Cool Vendors in Consumer Services, 2012"

Pico Projectors

Analysis By: Amy Teng

Definition: Pico projectors are very small projector modules that can be integrated into mobile devices, such as handsets or laptops, or used to create highly portable projector accessories for

mobile workers. They can be implemented using several technologies, including liquid-crystal-on-silicon imaging chips with light-emitting diode or laser diode illumination, microelectromechanical systems digital light processing technology, or laser diffraction.

Position and Adoption Speed Justification: A small pico projector module in 2012 will reach volumes of 3 cc to 5 cc supporting 720p display, making integration in personal devices (such as handsets) more practical. Challenges include low brightness, poor resolution and power consumption in battery-powered devices, cost (about $20 to $80 as a component, depending on specification and technology), heat dissipation and usability. Future devices are likely to include features such as keystone correction to facilitate use cases, such as table-top projection.

Laptop and media tablet use of this technology will require pico projectors with sufficient resolution to compete with their main screens, combined with innovative mechanical design.

First-generation pico projector modules small enough to embed in mobile phones emerged when Samsung introduced a Beam projector phone in MWC 2009, and a laptop using a pico projector was demonstrated by Asus in Computex 2008. During the past year, Sony established a PJ product line in digital video (DV) camera family with fully equipped pico projectors. In MWC 2012, Samsung reintroduced a pico projector smartphone, Galaxy Beam, with greater specification, longer battery life and slimmer design.

Smaller, second-generation components with better performance and power consumption will be required for large-scale adoption, and all pico projection technologies will continue to evolve for several years. The user demand for built-in pico projectors in personal devices, such as mobile phones, laptops and tablet devices, is low at this time and will take several years to establish.

User Advice: We don't believe users will accept the compromises in use ratio, price, portability and battery life required for a pico projector built into a mobile phone, so the likely short-term application is as an accessory for traveling workers. Built-in pico projectors, especially those using technologies such as laser diffraction (which doesn't require focusing), may be attractive for sales staff with a short face-to-face time with key prospects, and who want to display images or videos briefly on any available surface.

Business Impact: Handset and laptop vendors should consider offering pico projectors as accessories, and handset vendors with large portfolios should consider pico projectors in high-end business smartphones. Corporations with sales staff who have short periods of face-to-face time with key prospects, should also consider them as sales support tools.

Laptop and tablet vendors that want to create innovative form factors could explore pico projectors as alternatives to conventional displays beyond integrating them. In the longer term, pico projectors that work with image sensors may enable new gesture recognition technology (for example, sixth-sense technology).

Benefit Rating: Moderate

Market Penetration: Less than 1% of target audience

Maturity: Emerging

Sample Vendors: 3M; Asia Optical; Himax Display; Light Blue Optics; Micron; Microvision; Texas Instruments; Young Optics

Recommended Reading: "Emerging Technology Analysis: Pico Projectors, PC Technologies"

"Dataquest Insight: Teardown and Cost Analysis of Samsung's SPH-W7900 Projector Phone"

"Cool Vendors in Imaging and Display Devices, 2010"

"Dataquest Insight: Teardown and Cost Analysis of Lanye's N70 Projector Phone"

Device-Embedded Biometric Authentication

Analysis By: Ant Allan

Definition: Device-embedded biometric authentication is a specialized use of biometric authentication methods to improve the security of endpoint devices, such as notebook PCs, smartphones and tablets, using capture devices (sensors) and biometric feature extraction and comparison software built into the device itself. Because such a mobile device is essentially personal to one user, the mode is typically a one-to-one comparison of a probe biometric sample against the user's biometric reference stored on the device.

Position and Adoption Speed Justification: Biometric authentication has, so far, been embedded in two classes of mobile devices — notebook PCs and phones. Biometric-enabled notebook PCs are available from most major vendors and typically use fingerprint biometric authentication, although one vendor has also introduced embedded face topography biometric authentication. Fingerprint technology has been available on mobile phones longer, but until recently availability has been limited to certain geographies, and some vendors now offer embedded face topography biometric authentication.

Enterprises have adopted biometric-enabled mobile PCs to acquire an authentication method that offers improved user experience (UX) over legacy passwords and at a lower total cost of ownership (TCO) than a third-party biometric authentication product. A secondary goal has been to improve endpoint security of mobile PCs for the mobile workforce and to strengthen authentication to Active Directory (AD) and Windows networks, with biometric authentication pitched as an alternative to various token-based methods, such as X.509 smart cards. The ostensible convenience of biometric authentication, based on its early appeal among some users, such as senior managers, appears to have been a key driver to the sale of biometric-enabled mobile PCs. However, usability issues with fingerprints have led to a level of user disenchantment. Furthermore, in many enterprises, biometric authentication has been presented as an option, not mandated, and many users have simply chosen not to use it for personal reasons.

Thus, although there are significant numbers of biometric-enabled mobile PCs in enterprises, it is unclear how many enterprises and users are actually using the biometric authentication capabilities. And because the focus has so often been on convenience rather than security in many enterprises, all users are still able to authenticate with their Windows passwords, so there has been no net gain in security.

We have not yet seen significant enterprise adoption of fingerprint-enabled phones, and, despite our optimism last year, Gartner has seen no indication that enterprise interest is increasing or will increase. Phones supporting face topography for power-on authentication have emerged and, because the technology leverages the existing user-facing camera rather than requiring a specialist capture device, this is likely to become rather more common.

As enterprises increasingly adopt bring your own device (BYOD) policies for mobile devices, it's clear that enterprises simply can't mandate the use of any one biometric authentication method for power-on authentication for all endpoint devices. Furthermore, exploiting device-embedded biometric authentication across the network and downstream applications is not a viable strategy when enterprises are increasingly looking to support access to their networks and systems from a wide range of endpoint devices, only some of which may support embedded methods. Users will not tolerate having to use different authentication methods, depending on which of their (corporate or personal) devices they choose to use at a particular time. What's more, using different authentication methods for different endpoints provides an uneven risk profile, making some access via certain endpoints potentially more vulnerable. Enterprises must aim for a consistent approach.

For these reasons we have kept device-embedded biometric authentication in the Trough of Disillusionment and now consider that it will be obsolete before it reaches the Plateau as an enterprise technology, despite that fact that it will likely become mainstream for individual phone users (if not for PC users).

User Advice: Device-embedded biometric authentication can improve UX and improve endpoint security, but because of technology constraints, it is rather less suited to strengthening authentication to networks and applications. Biometric authentication as a replacement for existing PINs or passwords provides some increase in assurance, but for medium and higher risk uses it should be used as in addition to passwords; in addition, it provides increased accountability, even when used alone. A few users (a few in a thousand) continually struggle to use fingerprint biometric authentication reliably — for physiological reasons (such as poorly defined ridges), or simply because they find it difficult to properly interact with the sensor (the biometric industry refers to such users unkindly as "goats") — and many users have problems some of the time. Even with continued improvement in fingerprint-sensor technologies, we expect face topography or voice recognition to provide more consistency and universality. However, early implementations of face topography in consumer devices are not robust and can easily be fooled by photographs.

However, the benefits of using biometric-enabled notebook PCs and smartphones are limited to situations where all users are using company-issued, or at least company-specified, devices.

Mandating device-embedded biometric authentication as part of BYOD policies is a nonstarter. This problem isn't restricted to biometric authentication methods: Support for all kinds of more robust power-on authentication methods across different mobile OSs and handsets is variable. A best practice is to use other security controls, such as containerization, that avoid reliance on power-on authentication.

Even with company-issued notebook PCs, client experience to date suggests that user adoption of fingerprint biometric authentication will be low unless use is mandatory, eroding potential benefits for endpoint security. Where the goal is improved security, users who cannot reliably use biometric

authentication must be provided with an alternative, likely at a higher per-user cost. Where enterprises are considering using device-embedded biometric authentication on notebook PCs to improve security for access to networks and downstream applications, it must be noted that the method is really only a proxy for the Windows password: AD doesn't "know" that the user used biometric authentication and, potentially, a successful masquerade attack needs only knowledge of the user's Windows password. Furthermore, third-party tools may be required to fully manage configuration and usage.

A more robust strategy for access to the network and downstream or Web applications is to leverage the endpoint (notebook PC or smartphone) as just a platform for one or more capture devices — microphones for voice, user-facing cameras for face topography (or perhaps iris structure), keyboard for typing rhythm and so on — for back-end biometric authentication.

Business Impact: For mobile devices, such as PCs and phones, device-embedded biometric authentication provides endpoint authentication without the need for passwords or additional tokens. Thus, it has the potential to provide significant improvements in UX and reduced operational costs.

However, usability issues and a lack of consistency of technology across different endpoints and vendors significantly limits the potential value, and the approach is unsuited for access to the network and downstream or Web applications.

Benefit Rating: Low

Market Penetration: 1% to 5% of target audience

Maturity: Adolescent

Sample Vendors: Agnitio; AuthenTec; Google; Toshiba; Validity Sensors

Recommended Reading: "A Taxonomy of Authentication Methods, Update"

"How to Choose New Authentication Methods"

"Q&A: Biometric Authentication Methods"

Micro Fuel Cells

Analysis By: Jim Tully

Definition: Micro fuel cells (MFCs) are an alternative to batteries in mobile devices. They may be small enough for integration inside the device, or a little larger for use in an external power supply. Most fuel cells use hydrogen as the base fuel, but MFCs usually extract it from methanol — a hydrogen-rich liquid. MFCs can provide up to 10 times the energy storage capacity of a lithium battery but are not as good at delivering bursts of high power. This makes them more useful for battery charging than for primary power roles.

Position and Adoption Speed Justification: MFCs can be recharged almost instantaneously by adding more methanol — by either pouring it in or clipping in a new cartridge. This is a significant advantage over batteries, which can take several hours to recharge. Micro fuel cells are also environmentally friendly; the operating waste is only hydrogen and oxygen, which appears (in the form of pure water) as slightly increased humidity around the cell. Other forms of fuel cell, such as zinc-air and ethanol, are possible fuel sources for mobile devices — but are currently less prominent.

Portable fuel cells are appearing in commercially viable packages, but they are currently relatively large. In recent years, two factors of note occurred to affect the status of micro fuel cells:

- The considerable publicity surrounding exploding laptop batteries
- The authorization to carry fuel cells (and fuel cartridges) on commercial aircraft from January 2007

Despite these factors, micro fuel cells have not progressed far along the Hype Cycle over the past few years. Truly portable micro fuel cells, which could be incorporated into devices such as mobile phones, are still limited to the concept and prototype stages — with no commercial products available. It is possible that the problems of exploding batteries have created a perception of their fuel (commonly methanol), or the hydrogen produced in the cell, as a potential hazard, making people more cautious about fuel cells. The more surprising issue is the lack of progress following the aircraft authorization. The growing availability of electrical power at aircraft seats, and the ability of batteries to operate for the duration of many flights, may have negated this factor. Even so, the main driving force for mass-market expansion of micro fuel cells remains notebook computer users — rather than users of mobile phones, media players or other types of equipment — because of the higher power needs of notebooks compared with smaller portable devices.

Deployments are now occurring, but they center largely on military, exploration and other isolated environments. Demand from commercial users in mainstream enterprises has slowed during the past two years, probably as a result of travel restrictions. Cartridges giving three hours of laptop use are likely to cost approximately $5, which is acceptable for many situations — especially where urgency is involved. The overall equipment cost will still be relatively high when using fuel cells because a battery or supercapacitor will be required for delivery of peak power pulses. A bigger problem for deployment is the lack of immediate availability of cartridges, and the lack of a nationwide, or global, fuel supply infrastructure with appropriate standards for fuel quality, fuel concentrations, cartridge format, and so on. The latter problem is a more long-term issue and the main reason for our current "time to plateau" estimates. The availability of solar-powered chargers is another alternative for users in remote locations.

Delayed market rollout is a cause of concern for startup vendors in this area; bigger vendors are better positioned to cope. The first practical mass-market use for micro fuel cells with portable devices is likely to be in stand-alone battery chargers for notebook computers and mobile phones — some such products are already available. More-integrated configurations will follow. One of the most interesting developments in recent times has been the user-refillable hydrogen cartridge system from Horizon Fuel Cell Technologies, which allows users to generate their own hydrogen fuel from water. Developments such as this could lead us to change our assumptions about this

market. We will watch developments carefully. For now, we have retained the technology in the same position on the Hype Cycle as last year.

User Advice:

- Users of equipment in isolated areas should evaluate offerings in preparation for early adoption.
- Vendors of equipment such as PCs should establish relationships with micro fuel cell companies if they believe important classes of customers will benefit from them. These vendors should add their weight to finding a solution to the fuel distribution problem.

Business Impact:

- Longer working times will facilitate more powerful mobile devices and applications.
- Micro fuel cells have the potential to enable terminals with smaller footprints because of their smaller physical size (for comparable energy ratings) compared with batteries.

Benefit Rating: High

Market Penetration: 1% to 5% of target audience

Maturity: Emerging

Sample Vendors: Aquafairy; Hitachi; Horizon Fuel Cell Technologies; LG Electronics; NEC; Smart Fuel Cell; Sony; Toshiba

Recommended Reading: "New Product Marks the Consumerization of Hydrogen Fuel Cell Powered Chargers for Mobile Devices"

"Cool Vendors in Consumer Energy Management, 2010"

Embedded Wireless Cellular Modems

Analysis By: Hugues J. De La Vergne

Definition: Embedded wireless cellular modems are modems embedded in notebook computers and other consumer electronics devices to provide cellular connectivity. Because of the increase in speeds of cellular technologies to High-Speed Packet Access and Long Term Evolution (LTE), along with smaller form factors, such as media tablets, embedded wireless cellular modems have seen rapid growth.

Position and Adoption Speed Justification: Although removable modems are a mature technology, embedded modems have started to gain momentum as more end users want their PCs and consumer electronics devices to be regularly connected to the Internet. Growth in the embedded segment was limited historically because of users' concerns about having a device that supports an out-of-date cellular technology and the high prices of rate plans. End users preferred the flexibility that removable USB dongles offered, protecting buyers from rapid cellular technology changes. Historically, such changes have come several times faster than the normal laptop

replacement cycle. Although USB modems often have lower durability and performance than embedded cellular modems, the payback comes from greater notebook asset protection, because obsolete modems can readily be swapped out, whereas an embedded cellular solution can be difficult or impossible to change. In addition, USB dongles can easily be shared in an organization. With embedded cellular modems, the software differences from operators provide challenges from a common image perspective.

User Advice: The launching of LTE allows wireless networks to offer an improved user experience as speeds are comparable to those of the wireline experience, in some cases. With the expansion of multidevice data plans, small business and consumers should see improved pricing and should look to add embedded wireless cellular devices, such as media tablets and mobile PCs, to their network as opposed to Wi-Fi-only devices.

Business Impact: Embedded modems will affect telecommunications strategies and economics for mobile users with notebooks as organizations choose among the wireless communications options available.

Benefit Rating: Moderate

Market Penetration: 1% to 5% of target audience

Maturity: Early mainstream

Sample Vendors: Huawei; Kyocera; Novatel Wireless; Option; Pantech Wireless; Sierra Wireless; ZTE

Recommended Reading: "Forecast Analysis: Cellular Modems, Worldwide, 2009-2016, 1Q12 Update"

"Forecast: Removable and Embedded Cellular Modems, Worldwide, 2009-2016, 1Q12 Update"

Bluetooth 3.0

Analysis By: Mark Hung

Definition: Over the last decade, Bluetooth has become the de facto technology for wireless point-to-point connectivity. Bluetooth 3.0 and Bluetooth 3.0 + HS (collectively referred to as BT3.0; HS stands for "high speed") were introduced in 2009. BT3.0 includes all of the functionality of BT2.1 EDR, in addition to the following new features:

- Generic test methodology
- Enhanced power control
- Unicast connectionless data

The HS version adds support for Generic Alternate MAC/PHY and the 802.11 Protocol Adaptation Layer, which increases the speed to 24 Mbps.

Position and Adoption Speed Justification: Bluetooth 3.0 + HS requires both Bluetooth and Wi-Fi technologies to be present. BT3.0 is intended to support the increased need for personal devices to transfer larger file types, such as music and video. As an estimate, a 1MB file that is transferred in one minute with Bluetooth 2.1 could theoretically transfer in less than six seconds with Bluetooth 3.0 + HS using Wi-Fi's MAC/PHY layers.

The Bluetooth 3.0 + HS specification was approved on 22 April 2009. Expect Bluetooth transfers using Wi-Fi to be relatively trouble-free. With more than 2 billion Bluetooth-enabled devices, BT3.0 is expected to be a widely deployed capability as devices are replaced (typically every two years). Most of the current Bluetooth chipsets will migrate at least to the 3.0 specification. Expect BT3.0 to appear initially in notebook computers and high-end smartphones and then migrate during a five-year period to all devices that support Bluetooth today. Expect laptops to support the new HS specification, while smartphones will use either BT3.0 + HS or the newer BT4.0 technology. BT3.0 + HS (not BT3.0) may see its adoption stunted due to competition from Wi-Fi Direct.

User Advice: For vendors, there is little technical or commercial downside to implementing BT3.0. Laptop vendors may find that Wi-Fi Direct is more straightforward, but they may wish to maintain compatibility with smartphones that use BT3.0 for lower power operation. For end users, no proactive early adoption is recommended. Instead, users should wait until the technology arrives in products at a negligible price premium, which started happening by the end of 2011.

Business Impact: Businesses will have another option for peer-to-peer networking. The major issue for businesses will be controlling the use of the technology and ensuring that it complies with security requirements. The new higher rates should broaden Bluetooth's adoption.

Benefit Rating: Low

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Broadcom; CSR; Marvell Technology Group; Qualcomm Atheros; Texas Instruments

Voice to Text on Mobile Devices

Analysis By: Carolina Milanesi

Definition: Voice to text on mobile devices refers to embedded applications that enable any spoken word to be converted into readable text that can then be used in other applications including email and messaging services.

Position and Adoption Speed Justification: With touchscreen devices becoming mainstream, there is a need for an easier input mechanism for tasks such as email and text messaging. In 2011, the most significant development in this space has come from Apple. With the launch of the iPhone 4S voice to text had a new benchmark in the shape of Siri.

Although Siri is marketed as a personal assistant — and delivers more than voice to text as it can answer questions, performs actions and make recommendations — it does convert your voice into text messages and email as well as Google search questions. In the most recent version of the iPad, Apple added Dictation, an app that allows you to do exactly what it says on the label: dictate text. A digitized recording of your voice and some user information are sent back to Apple to learn more about the user and return more precise text as the server learns about you. Both Siri and Dictation are rumored to be powered by speech recognition veteran Nuance, although both Apple and Nuance have never confirmed this.

We expect other companies in the mobile device arena to follow Apple and Siri by adding voice as a user interface element. Samsung recently added S-Voice — a lighter and less intelligent facsimile of Siri — to the Galaxy S III. Winning solutions going forward will be a mix of on-device and cloud-based services.

User Advice: Voice to text can be quite effective for short, straightforward messages. It is less reliable for long, complicated messages and when the speech is taking part in a noisy environment such as a moving car. Performance also depends on the user's clarity of speech. We expect performance to continue to improve.

Business Impact: A good voice to text client will simplify data input for touchscreen devices that are very popular in the current market but which can be cumbersome when it comes to email and messaging. Once the applications are more reliable, organizations could consider employing them to enable users to add data to specific forms, such as expense claims or order forms.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: Apple; Google; Microsoft; Nuance; Samsung Electronics

Wireless Video — 2.4/5GHz

Analysis By: Mark Hung

Definition: Wireless video, broadly defined, is any over-the-air video transmission, whether it is broadcast (one-to-all), multicast (one-to-many) or unicast (one-to-one). This video stream can be transmitted over the public spectrum (broadcast frequencies or WAN) or inside a home or enterprise using an unlicensed spectrum (wireless LAN [WLAN]). We are limiting the definition of this technology to wireless video transmission using the 2.4GHz and 5GHz bands in a WLAN setting.

Position and Adoption Speed Justification: Wireless video technologies can be categorized along several different axes:

- Spectrum: 2.4GHz, 5GHz or 60GHz

- Standards-based or proprietary: Wi-Fi (IEEE 802.11) is the most popular physical-layer standard for WLAN
- Network topology: Star (with a wireless router or access point [AP] in the middle) or peer-to-peer (P2P)
- Throughput: This is largely a function of the underlying physical-layer standard, although the use of compression at a higher layer can increase the overall throughput

In the 2.4/5GHz bands, wireless video has largely standardized on the 802.11a/b/g/n specification, and it is expected to use 802.11ac when that standard is ratified at the end of 2012. Given the reach in these frequency bands (typically 100 to 200 feet in an indoor setting), both the star and P2P network topologies may be used. The star topology is typically used for whole-house video streaming, whereas P2P is used for in-room transmission. For whole-house video streaming, the application developers have usually used the APIs provided by the various OSs (e.g., Windows, Mac OS, iOS, Android and Linux) to enable the capability. However, for P2P video streaming, a few competing technologies have arisen that sit on top of 802.11 to support wireless video:

- Wireless Home Digital Interface (WHDI): This is a proprietary wireless video standard promoted by a single semiconductor vendor (Amimon), along with a number of Asian consumer electronics (CE) companies. It uses the traditional 5GHz spectrum and is largely based on conventional 802.11a technology.
- Intel WiDi: Intel's proprietary implementation of Wi-Fi Display as a prestandard technology. In addition, Intel enhanced the overall performance of the system by compressing the video signal before sending it out over the wireless medium.
- Apple AirPlay: Apple's proprietary technology that enables video streaming from an iPhone or iPad to a TV via a second-generation Apple TV. This is accomplished using standard 802.11n. Although it may seem that the device is streaming video directly to a TV, it actually operates in a star topology via the wireless router, AP or repeater.
- Miracast (aka Wi-Fi Display): Wi-Fi Alliance's first wireless audio/video standard, designed to ride on top of the Wi-Fi Direct technology that it has developed using a P2P topology. It supports 802.11n and future 802.11 standards, such as 802.11ac and 802.11ad.

Although Amimon is still pushing ahead with its WHDI standard, it has not seen much traction in the past and is not expected to be a major player in this market. For the other vendors, we expect most of them to coalesce around the new Miracast standard once it has been ratified and it is adopted by the computing, communications, and CE equipment manufacturers. This is demonstrated by the broad support it receives among the companies that are working on the standard. The standard is expected to be ratified by the end of 2011, and the first products supporting it will appear in 2012.

User Advice: Although wireless video streaming is feasible in both the 2.4GHz and 5GHz bands, the user experience is much better in the 5GHz band due to the larger number of available channels. Therefore, users should ensure that all their equipment can support the 5GHz band for optimal performance.

Electronic equipment manufacturers should take advantage of the cost-downs in the chipsets to drive wider adoption of dual-concurrent (simultaneous 2.4GHz and 5GHz operation) routers and APs so that both data and video can be well-supported. Client device manufacturers (PCs, smartphones, and CE) should enable 2.4/5GHz technology more widely in their product portfolio to take advantage of these capabilities.

Business Impact: Wireless video can improve corporate communications and training methods, thus improving efficiency and lowering travel costs. In CE and computing devices, wireless video may soon become a checklist item that manufacturers must implement on their platforms.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Amimon; Apple; Broadcom; Cavium Networks; Intel; Qualcomm Atheros; Samsung; Sony

Recommended Reading: "Emerging Technology Analysis: Consumer Electronics Technologies, Wireless High-Definition Multimedia Interface Cable Replacement"

Climbing the Slope

Haptics

Analysis By: Tuong Huy Nguyen

Definition: Haptics is a tactile or force-feedback technology that leverages a person's sense of touch by applying vibrations and/or motion to the user's fingertips. This stimulation can assist the technology in the development of virtual objects on the device screen. In its broad sense, haptics can be any system that incorporates tactile feedback and vibrates through a sense of touch.

Position and Adoption Speed Justification: Tactile haptic feedback on mobile handsets has been around for a while and is mainly used to complement ring tones. Adoption into other applications stagnated until the recent trend in touchscreen displays. Despite this, the implementations that emerged from this hype were not compelling enough to drive further interest in this technology. This is partly due to bad implementations and the lack of high-quality haptic routines that complemented the touch experience. Recent developments have improved on these experiences and show the value of haptics. They include:

- Efforts from intellectual property (IP) holders, such as Immersion, to provide software development kits and predefined routines for developers are helping show the value of haptics.
- Leading publishers/developers, such as Rockstar Games, Sega and Konami, are currently leveraging Immersion's development platform to integrate haptics into a number of their games.
- In the prior year, Artificial Muscle launched the mophie pulse, a vibrating gaming case for iPods.

- At CES 2012, Pantech launched the first tablet (Element) to feature HD haptics.

On mobile devices, the technology is moving toward the plateau. A majority of mobile phones already provide some type of basic (low-fidelity, phone vibration mode, basic touch feedback loop "buzz" haptic feedback), and a growing number of developers are leveraging this capability. Because the value has yet to be significantly demonstrated, we expect it to remain in this position for two to five years — until subsequent developments can provide high-fidelity haptics (from piezo and electrostatic solutions) at a more competitive price and providing a richer experience. These developments would increase adoption among handset vendors as well as developers.

Market penetration and positioning have been updated to reflect penetration of basic (low-definition) haptics, as well as higher-fidelity haptics, in mobile devices.

User Advice: All portable, connected consumer electronic devices that integrate a touchscreen interface need some degree of haptic feedback. Devices lacking this will be at a severe competitive disadvantage.

Business Impact: Haptic feedback offers potential improvements in speed and quality for input and interaction with mobile devices. The growing trend in touchscreen phones has spurred demand for tactile haptic feedback on devices. Haptic feedback greatly enhances the user experience for touchscreen devices by providing a tactile response to acknowledge user actions.

Benefit Rating: Low

Market Penetration: More than 50% of target audience

Maturity: Adolescent

Sample Vendors: Artificial Muscle; Force Dimension; Haption; Immersion; Moog; Novint Technologies; Pacinian; Sensable Technologies; Senseg

Recommended Reading: "Emerging Technology Analysis: Success of Haptics for Media Tablets and Smartphones Hinges on New Application Development"

"Competitive Landscape: Touch Controller Market Worldwide, 2011"

MEMS Gyroscopes

Analysis By: Tuong Huy Nguyen

Definition: A gyroscope is a device containing a moving mass that facilitates the sensing of position and motion in three-dimensional space (pitch, roll and yaw). Semiconductor micro-electromechanical systems (MEMS) technology shrinks the gyroscope into a very small size using silicon components. Traditional gyroscopes typically utilize a spinning mass, while MEMS versions normally use linear motion.

Position and Adoption Speed Justification: The use of MEMS gyroscopes is growing. When used with accelerometers, gyroscopes provide enhanced spatial precision data for numerous

applications — improving the user experience for applications involving motion sensing. Multiaxis gyros can also be used as a higher-performance, power-efficient alternative to a multiple-accelerometer solution (detecting rotation, roll, pitch and yaw), or an accelerometer and magnetometer combo solution.

MEMS gyros have applications across a broad range of market segments, including military, industrial, sports and health, and imaging. We expect a majority of the use will be in mobile devices. Initial adoption will be in higher-end mobile devices with accelerometers and magnetometers. Demand for more accurate spatial positioning, enhanced interactive experiences involving gesture recognition, and improved sensing will drive growth in MEMS gyroscopes. Growth will also be driven by benefits across numerous applications, such as GPS, location, navigation, safety, healthcare, gaming and imaging. They are already being used in numerous consumer electronics devices (such as the Nintendo Wii Motion Plus controller, remote-controlled helicopters, digital cameras and camcorders). The iPhone 4 was the first mobile phone with a MEMS gyroscope. As predicted, the debut has spurred a trend in phones and tablets that we expect to continue. Some of the more notable recent devices with gyroscopes include iPad 2, Motorola Xoom, Samsung Galaxy S3 and LG Lucid. Further advances in the technology, such as smaller footprint, and integrated motion processing solutions with multiple-axis gyroscopes, will make this feature increasingly available across consumer electronic devices.

Despite the benefits, a number of factors potentially hinder uptake for MEMS gyroscopes in consumer electronic devices. Cost remains an issue for more price-sensitive applications, such as mobile phones. More importantly, the full potential/value of MEMS gyros has yet to be achieved. The technology itself is well-established, but most applications do not take advantage of this feature — relying primarily on a combination of the accelerometer, magnetometer and GPS to achieve the necessary location information. Companies such as InvenSense have offered software development kits (SDKs) to promote the use of and help developers better leverage the gyroscope. Similarly, power consumption is also an issue. Although companies, such as STMicroelectronics, have developed solutions that make the impact practically negligible, the gyroscope still taxes battery life in (higher-end) devices that are already pushing the limits of power maximization.

We expect this technology to continue to evolve (decreased power consumption, smaller physical footprint) and drive adoption — well after the devices are beyond the Plateau of Productivity.

User Advice: Handset vendors should use this technology as a competitive differentiator for their higher-end devices, especially those targeting specific market applications, such as GPS and navigation, imaging, health and fitness, and gaming. Vendors can also leverage the gyroscope to improve user interfaces. Similar advice can be applied to consumer electronics vendors that want to include MEMS gyroscopes in their devices. Enterprises and vertical industries such as healthcare should evaluate the benefits of improved accuracy from MEMS gyroscope-enabled devices and compare them with current, as well as alternative, solutions (as MEMS gyroscopes will likely be limited to the high end in the next two years). For less cost- and power-sensitive markets, earlier implementation will be more viable.

Communications service providers (CSPs) and application developers should work together to provide optimized content and services to gyroscope-enabled devices.

Business Impact: MEMS gyroscopes will provide a higher level of accuracy because of the additional data they obtain. Consumer benefits, such as improved user interfaces, a more immersive gaming experience, higher image quality and more accurate navigation and location, can be leveraged by CSPs, handset vendors and application developers. Improved accuracy can also be leveraged by enterprises for uses such as fleet management and navigation, as well as vertical industries, such as medical for healthcare monitoring. In both segments, the gyroscope can be a valuable competitive differentiator.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Analog Devices; InvenSense; STMicroelectronics

Recommended Reading: "Emerging Technology Analysis: MEMS Gyroscopes Provide Numerous Enhancements to Mobile Devices"

"Emerging Technology Analysis: Augmented Reality Shows What Mobile Devices Can Do"

"Competitive Landscape: Portable Navigation Devices, 2010"

"Forecast: Consumer Location-Based Services, Worldwide 2008-2014"

"Competitive Landscape: Nonoptical Semiconductor Sensors"

Phone Bar Code Reader

Analysis By: Sandy Shen

Definition: A phone bar code reader is a software client that works with a phone's camera to capture and decode bar codes.

Position and Adoption Speed Justification: Bar code readers are used to decipher data so that users can quickly access content and eliminate the need for text input. Bar codes can be used to encode URLs, business cards, product information and marketing campaigns. For example, a company can put bar codes on printed advertisements, billboards, posters, brochures and product packages, and users can scan the bar codes with a phone's camera to obtain the corresponding information. There is no specific camera phone requirement for this technology, and a basic Video Graphics Array camera will work.

Bar codes can be one-dimensional (1D), two-dimensional (2D) or 3D (using color to create the third dimension). However, 3D bar codes need server support to decode the data effectively, and require a live data connection from a phone, which currently limits market penetration. The 2D bar code is the code used most often by mobile phones, and there are about a dozen 2D bar code codes with different data capacities. Quick response code (QR code) and Data Matrix are used most often and can be read by most readers, while less used codes may require a special reader. QR code is the

most often used code for marketing, while others can be used for more specialized purposes, such as manufacturing, retail, logistics and ticketing. The 1D bar code is often used in warehousing, logistics and retail for internal tracking, rather than for customer interaction. The 3D bar code is the least seen in the market, and requires dedicated readers.

Bar code readers can be downloaded from most app stores, although performance varies. A number of phone manufacturers also preinstall the reader. Penetration of the installed mobile phone base is still low, on average, less than 10% globally, and mostly on smartphones. Lack of user awareness, the need to download readers and unfamiliarity with the technology all deter more frequent use. However, more companies with recognizable brands have started to include bar codes in their marketing campaigns and materials. This will help increase user awareness.

User Advice: Organizations can include bar codes in their marketing materials and product manuals to offer more and interactive information. Companies should look for vendors that offer solutions to manage the content remotely and dynamically, and that provide reporting and analytics.

Business Impact: Companies can use bar codes for interactive marketing, and to offer more useful information. Communication service providers (CSPs) can expect higher data traffic, content downloads and advertising revenue if they have a hosting service.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: 3GVision; CodeZ QR; ColorZip Media; Microsoft; NeoMedia Technologies; Nokia; QuickMark; Scanbuy; Semacode

Recommended Reading: "Mobile Check-In for Airlines: Lessons From a South American Airline"

"Dataquest Insight: Music Festival and Amusement Park Show Potential of Mobile Ticketing"

Electronic Paper

Analysis By: Jim Tully; Amy Teng

Definition: Electronic paper refers to several reflective display technologies that do not require a backlight and can be viewed in conditions of good ambient illumination. Bistable pixels — that remain in a particular state after the power is removed — are used. For static images, this results in ultralow energy consumption. Most electronic paper technologies involve physical movement within the pixel to facilitate a change from light to dark, or to change color. The performance achieved has therefore been slower than with other displays, such as LCDs.

Position and Adoption Speed Justification: We class several technologies as electronic paper, including:

- Electrophoretic — This is the most mature electronic paper technology, notably supplied by E Ink. It utilizes organic plastics rather than glass, giving physical characteristics that are surprisingly rugged. The technology is based on pixels composed of charged particles suspended in a fluid. There is much interest in the development of the flexible versions of these displays, such as those produced by Polymer Vision (acquired by Wistron) and Plastic Logic. Faster versions are also being developed, with the ultimate aim of full video speeds.
- Electrowetting — An electrical charge causes a colored oil to spread across the surface of the pixel. Absence of the charge causes the oil to retreat into a tiny area at the corner of the pixel, producing a black color. The technology was developed mainly by Liquavista (acquired by Samsung Electronics).
- Micro-electromechanical systems (MEMS) — Notably driven by Qualcomm's Mirasol division. These displays employ tiny plates that move if a voltage is applied. In one position, the plate allows light to pass into the pixel and be reflected to the user as a visible pixel; in the other position, the light is absorbed.

Other related technologies use nanochemical changes, rotation of spherical-shaped pixels, and electrochromic properties.

Touch sensitivity can be added to electronic paper by adding a touch layer over the front or back of the display. Addition to the rear of the display offers the added benefit of a higher quality (and brighter) image, since reflected light does not need to pass through the touch-sensitive layer. Touch technology allows features such as the highlighting of words or adding handwritten notes in electronic books.

The position of electronic paper on the Hype Cycle is an average of these various subtechnologies.

The initial major applications for electronic paper are electronic books (e-books), signage (in retail and roadside applications) and small information-centric screens (in mobile phones and music players). The most visible uses of the technology to date are in the Amazon Kindle, Sony Reader, and a number of other e-book products. The technology was also prominently used in Motorola's Motofone F3 mobile phone and Samsung's Alias 2 dual-hinge mobile phone. Some uses of electronic paper are clearly already in widespread use, but the real potential is for color and higher-speed versions that are still emerging.

Low energy consumption is the main driver in most electronic paper applications. Low cost is another driver: for low-end mobile phones and other applications such as smart labels and electronic tags, and inexpensive mobile devices that do not require full-motion video. Another driver is the readability of these displays in bright sunlight, making them ideal for use outdoors and in car dashboards. These applications are likely to drive further commercialization during the next two to three years. Refresh speed and color support remain limiting factors for the current generation of electronic paper technology. The declining cost of LCDs and the increasing attractiveness of organic light-emitting diode (OLED) displays are challenging a number of application areas for electronic paper, and this is moderating some of the growth opportunities for the technology. However, the ultra-low-power characteristics are unmatched by any other display technology, and this will be critically important in many applications.

User Advice: Users and vendors should start to evaluate this technology in light of their specific business needs. These will vary by the need (or not) for color and video. Applications with images that are fixed for a period of time (such as e-books, labels, low-power battery-operated consumer goods such as radios and watches, debit cards and battery condition monitors) are already appropriate for widespread usage depending primarily on price.

Other applications requiring color and video will probably find LCD or OLED displays to be most suitable. Where ultralow energy consumption requirements dominate, electrowetting- or MEMS-based electronic paper should be considered.

Business Impact:

- Use of wireless battery-powered signage is likely to bring significant benefits to some classes of business, most notably in the retail sector because of the ability to make frequent changes to the displayed content.
- New product classes and new services could also be facilitated with the help of electronic paper.
- The "Internet of Things" will promote the addition of low-cost embedded technology into large numbers of everyday objects. Low-cost, low-power simple displays are likely to become an important component of this emerging business opportunity.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: E Ink; Magink; Ntera; Qualcomm; Samsung Electronics; SiPix

Multitouch Displays

Analysis By: Angela McIntyre; Jon Erensen; Leslie Fiering

Definition: Multitouch refers to a touchscreen interaction technique in which multiple simultaneous touchpoints and movements can be detected and used for screen navigation or to control objects (such as sorting a series of pictures) on the screen. Various combinations of two or more fingers may be used together to create control gestures. A user may, for example, zoom into a picture by placing a thumb and an index finger on a touchscreen and then moving them apart. To zoom out, a user would move the same two fingers back together in a pinching motion.

Position and Adoption Speed Justification: Products such as the Apple iPhone, iPod touch, iPad and Android-based smartphones and tablets are rapidly advancing the adoption of multitouch technology. The inclusion of this technology in Apple's products has attracted wide attention from competitors in these markets and vendors in adjacent markets looking to use multitouch to improve user interface and create a differentiator with competing products.

Gestures can create shortcuts for performing a group of actions with a pen or a finger. The direction and shape of the gesture can dictate the exact actions. Good implementations provide visual clues regarding the effects of the gestures on the applications and even build on the gestures — for example, by providing acceleration if a "flick" or sweeping gesture is held long enough. Multitouch gestures supported by Apple's iOS are a default standard. Multitouch-capable touchscreens are becoming expected features by consumers on smartphones and media tablets. But other devices, such as PCs, can use multitouch-enabled touchpad pointing devices instead of mice as external peripherals, integrated into the keyboard of desktop PCs, or built into laptops near their keyboards. Multitouch screens add $60 to $100 to the bills of materials of mobile PCs, which is low enough to encourage consumer adoption. Multitouch can be implemented in multiple touchscreen technologies, including capacitive, resistive and optical. Multitouch technology continues to evolve, and in-cell displays are expected on iPhone 5 this year. With in-cell displays, the touch module resides inside a display's color filters rather than above them, allowing for a thinner touch panel.

Interest in multitouch technology is considerable, but to work well it requires tight integration between software (OS, user interface and applications) and hardware. Adapting an existing OS for multitouch capabilities takes considerable effort, but operating systems in addition to the iOS have added multitouch capabilities, including Microsoft Windows 7, the BlackBerry OS, Android, webOS, Ubuntu and Apple's Mac OS X Lion, and Microsoft Windows 8 (expected in October 2012). There is strong momentum in the software application ecosystem for multitouch technology, and the adoption of multitouch is increasing rapidly in mobile phones, media tablets and portable consumer electronics devices. Multitouch applications on PCs have struggled to prove their value to consumers, but the inclusion of multitouch in OSX Lion accelerated consumer demand for this feature in PCs.

User Advice: Multitouch is an enabling technology and does not, by itself, guarantee successful products.

Apple's successful introduction of the iPad will increase OEM experimentation on the market with new media tablet designs and innovative form factors for multitouch PCs. Of the thin ultraportable mobile PC models brought to market this year, about 15% will have touch-enabled screens. However, flooding the market with multitouch-enabled devices is no guarantee that consumers will embrace multitouch computing on PCs in 2012. Hardware OEMs must ensure that multitouch capabilities are tightly integrated with their devices' user interface, OS and applications.

Software developers need to ensure that their applications apply consistent gestures and user interface design rules throughout.

Semiconductor vendors targeting the touchscreen market need to provide user interface solutions and complete reference designs to capitalize on emerging opportunities. They must understand how many resources are required to customize touchscreen products for the consumer market. They must also plan ahead — using in-house software, applications and systems expertise — to shorten the time-to-market for new design wins.

Business Impact: We expect multitouch-enabled touchscreens or touchpads to be widely adopted in smartphones, media tablets, notebook PCs, all-in-one desktop PCs and portable consumer

electronics devices. Multitouch technology has the potential to transform the way consumers interact with the electronics they use every day, enabling totally new input and control mechanisms. As a result, multitouch will impact usage models and have a significant impact on product design. This impact can already be seen in handsets with full-screen devices lacking hardware keypads and buttons. Multitouch could have similar impact in the PC market on traditional keyboard/mouse input devices, especially if the media tablet form factor continues to gain traction.

In five to 10 years, PCs with multitouch capabilities are likely to grow from a negligible percentage of the market to the majority. Although most touch-enabled PCs are shipped for commercial use, the future transformation to multitouch PCs will be led by the consumer market and will be slower in business until touch-based, productivity applications have demonstrated proven benefits. Microsoft may lose significant market share to Apple if the Windows 8 OS does not provide a multitouch user interface on par with Apple iOS and Mac OS X Lion.

Benefit Rating: Transformational

Market Penetration: 20% to 50% of target audience

Maturity: Early mainstream

Sample Vendors: 3M Touch Systems; Apple; Atmel Corporation; Cirque; Cypress Semiconductor; Samsung; Synaptics

Recommended Reading: "iPad and Beyond: What the Future of Computing Holds"

"Multitouch Will Be One of the Most Disruptive Technologies of the Decade"

"CES 2012: Multitouch Voice and Gesture Interfaces Combine on Future Devices"

"Competitive Landscape: Touch Controller Market, Worldwide, 2011"

High-Performance Multicore Application Processors

Analysis By: Jon Erensen; Michele Reitz

Definition: High-performance multicore application processors have clock speeds of more than 1GHz and symmetric multiprocessing cores. Processors in this category include Texas Instruments' Open Multimedia Application Platform (OMAP) 4, Qualcomm's multicore Snapdragon, Nvidia's Tegra 3 and Tegra 2, and Samsung's Exynos 4412 and HiSilicon Technologies' K3V2. High-performance multicore application processors include discrete application processors and integrated cellular baseband/application processor solutions.

Position and Adoption Speed Justification: Smartphones and tablets require additional processing power to handle full-resource-intensive operating systems and demanding applications, such as high-definition video, gaming, augmented reality and context-aware computing. High-performance multicore application processors have become a standard feature on high-end and midrange smartphones. Quad-core solutions are available and will gain in popularity, especially as vendors introduce solutions with additional low-power cores that will handle traditional tasks and

allow the high-performance cores to only be used when that level of performance is necessary. There are many advantages to having multiple cores, including the ability to distribute resource-intensive applications efficiently across cores and to have different applications running simultaneously on different cores. However, there is a challenge to overcome, in that operating systems and applications have to be designed to take advantage of symmetric multiprocessing architecture — and programming for multicore systems can be more difficult. The tools are now available to do this, but application developers need to ensure they take advantage of low-power cores when they can and not overly rely on the high-performance cores because of the potential impact on battery life.

User Advice: Handset and tablet OEMs will need to use multicore solutions at the high end of the market, but they need to pay careful attention to power consumption. Handset OEMs must realize that not all cores are created equal and that semiconductor vendors have different strategies when it comes to multicore implementations and the ability to use low-power cores. Offloading tasks that do not require high processing power will be critical. It will also be important to consider the support available for these processors from operating systems and applications.

Business Impact: This category of application processor will allow mobile phones and tablets to have portable computing capabilities that in the past were limited to PCs. This will allow phone users to accomplish more resource-intensive tasks without a PC, and could therefore increase their productivity while on the move.

Benefit Rating: High

Market Penetration: More than 50% of target audience

Maturity: Mature mainstream

Sample Vendors: Intel; Marvell Technology Group; Qualcomm; Renesas Electronics; Samsung; STMicroelectronics; Texas Instruments

Recommended Reading: "Market Trends: Mobile SoC Portends the Convergence of Application Processor, Cellular Baseband and Wireless Connectivity, 2012"

"Market Share Analysis: Mobile Phone Application-Specific Semiconductors, Worldwide, 2011"

"Intel's Medfield Seeks to Challenge Market Dominance of ARM-Based Mobile Application Processors"

"Qualcomm's Reference Design Will Assist Chinese Manufacturers in the Low-Cost Smartphone Market"

"Market Trends: Worldwide, Functional Integration Road Maps Are Essential to Exploit New Opportunities in Smartphones and Media Tablets, 2012"

802.11n

Analysis By: Tim Zimmerman

Definition: 802.11n is the latest wireless LAN (WLAN) standard ratified by the IEEE. Improvements have expanded the throughput and range of 2.4GHz or 5GHz. A single spatial stream operating in a 20MHz channel width can achieve 75 Mbps throughput, compared with the 54 Mbps of a similar 802.11a or 802.11g solution. However, most vendors offer two or three stream radios that are capable of up to 450 Mbps. Like previous 802.11 standards, 802.11n provides backward compatibility with 802.11a, 802.11b and 802.11g (a/b/g) standards.

Position and Adoption Speed Justification: The market movement to 802.11n has been steady. Many vendors continue to report that more than 90% of new access points purchased are now 802.11n, although they continue to be purchased for different architecture considerations — autonomous versus coordinated; controller-based versus in the cloud; or with one, two or three integrated radios within the access point.

User Advice: IT leaders should consider 802.11n for all their WLAN requirements. The number of radios within an access point, as well as the number of spatial streams supported and type of multiple input/multiple output (MIMO) support needed, will be determined by the enterprise WLAN requirements, including capacity and level of service. Vendors will still have points of differentiation that will not only improve wireless network performance in terms of capacity and robustness of communication, but will also create the need for use case testing, because vendor implementation choices will impact data, voice and video applications.

Business Impact: 802.11n should be considered for all WLAN scenarios within the enterprise, including small branch, remote office or large enterprise solutions. We believe that 802.11n will enable sufficient bandwidth and required capabilities (such as quality of service) for enterprises to consider for moving not only data, but also voice and video for many enterprise applications to the WLAN.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Aerohive Networks; Aruba Networks; Cisco; HP; Meraki

Recommended Reading: "Magic Quadrant for Wireless LAN Infrastructure"

"Use Best Practices to Implement a WLAN"

"Best Practices for WLAN Site Surveys That Save Money"

AMOLED

Analysis By: Mikako Kitagawa

Definition: Active matrix organic light-emitting diodes (AMOLEDs) consist of pixels of electroluminescent organic compounds "printed" in a matrix onto a base layer. This base layer is currently glass and will be further developed to use flexible polymers in the future. Unlike liquid crystal displays, OLED displays do not require a backlight and consume very little power, making them suitable for battery-powered devices. AMOLEDs use a thin film transistor (TFT) to control the pixels.

Position and Adoption Speed Justification: One of the biggest challenges for this technology is its lifetime compared with LCDs, but this depends on the application. In mobile phones, lifetime is slightly less important. Because the replacement cycle ranges from 12 to 36 months, users are likely to upgrade prior to the end of life of the AMOLED. Furthermore, polymer LEDs have been introduced in recent years and have been shown to have comparable lifetimes to LCDs. The other issue is yields, which factors into cost. AMOLED yields are approximately 60% to 70% (compared with more than 90% for LCDs). Further improvements in scale and technology for OLEDs during the next five years will allow this technology to be implemented in mass-market devices. Viewability in direct sunlight is also a problem for AMOLEDs, but the development of Super AMOLED has slightly mitigated this issue.

Many opportunities are available on other consumer electronics devices. Aside from mobile phones, AMOLED screens are currently used in a number of portable media players and digital still cameras. Although AMOLED displays continue to gain traction in the phone market, most AMOLED phones available are still Samsung devices because Samsung is the leading producer of AMOLED screens. Samsung's financial strength enables it to make a huge investment into AMOLED R&D and manufacturing so that its competitors cannot compete easily. Capacity constraints have led vendors such as HTC to seek alternative display technology for their higher-end devices.

AMOLED for devices of 11 inches and larger continues to be too cost-prohibitive to be viable. However, for PCs, there have been expectations for AMOLED for several years as AMOLED laptops have been used as showcases for PC manufacturers at tradeshows such as the Consumer Electronics Show. However, there is still no product equipped with AMOLED as of 1H12. The cost performance of AMOLED is the biggest hurdle for AMOLED-based laptops as low price and high volume is the mainstream business model for the laptop market. Manufacturers have less investment in AMOLED-based laptops as the ROI is very limited. For TVs, Sony used to manufacture AMOLED TV, but discontinued the product line in 2010.

User Advice: Vendors should continue to monitor AMOLED along with other emerging display technologies but should only implement this technology in their devices when pricing can compete with LCDs. Potentially improved battery life (from lower power consumption) over LCDs should also be considered. Early adopters will have the advantage of a superior technology — such as handsets with better color, contrast and viewing angles, as well as better response times (benefiting video applications).

Vendors can also benefit from using this lower-power-consuming technology as part of their "green" initiatives. Since it is a technology value-add that consumers can easily recognize, AMOLEDs can also be used in higher-end devices to command premium retail prices. For large-size

displays, the ROI from AMOLED devices is questionable as the costs compared with the value for the customers from the technology is not well balanced.

Business Impact: AMOLED screens are a lower-power, higher-performance alternative to traditional LCD screens. Recent developments have improved the life of these displays, making them competitive with LCDs. Although AMOLED screens are more expensive than a comparably sized LCD (due to factors such as yield and scale), the manufacturing technology to make OLEDs is potentially of far lower cost (because it does not require additional components, such as a backlight or diffusers) than that used for LCDs. Moreover, OLEDs provide better color, contrast and viewing angles, as well as better response times (which are good for video and gaming applications), benefiting handset OEMs across their entire lineup. Vendors can also benefit from using this lower-power-consuming (emissive) technology as part of their green initiatives. Improved performance over LCDs will have the greatest impact in the midrange to high-end, while the cost savings will affect lower-end devices the most.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Cambridge Display Technology; LG; Samsung; Sony; Universal Display

Magnetometer

Analysis By: Annette Zimmermann

Definition: A digital compass, or magnetometer, is a sensor that measures the earth's magnetic field to determine the direction to the magnetic poles. The implementation of three-axis compasses or magnetometer sensors, combined with accelerometer sensors, is critical for mobile devices in order to provide tilt compensation when they are not held horizontally.

Position and Adoption Speed Justification: The proliferation of location-based services has pushed more vendors — such as Nokia, Samsung, Apple, Motorola, HTC and Research In Motion — to include a digital compass in their smartphones. A magnetometer combined with a three-axis accelerometer is particularly helpful when pedestrian navigation functions are used, because it indicates the direction the user is facing. There are many use cases for this technology, and developers have recognized its benefit by providing numerous applications for iOS, Android, Symbian and Windows Phone 7. We see mobile location-based games such as those that use geocaching benefiting from this technology, especially in combination with GPS. Other games (not necessarily location-based games) can also make use of a digital compass. Augmented-reality applications, indoor positioning and outdoor activities such as hiking, biking and camping are other areas of application.

The strong market uptake of smartphones has increased the penetration of devices with an integrated digital compass — and this feature is now also appearing in more midrange devices such as the Huawei U8800 and HTC Wildfire. Thanks to Google's Android platform — which promotes the use of various location services such as Google Maps, Google navigation and location search —

magnetometers will almost automatically move into lower-price segments that vendors such as Alcatel, Huawei and ZTE are aiming at. Part of Nokia's strategy has been to include this technology in more devices, but with its move to Windows Phone 7 we may see the technology enter its midrange portfolio a little later, once Nokia has brought Windows Phone 7 devices into its midtier (not expected before the end of 2012).

The market for motion sensors is accelerating with gyroscopes in combination with accelerometer modules, such as magnetometers, helping to improve motion-based activities on portable devices, including games on tablets and smartphones. Magnetometers are especially useful in applications that rely on magnetic north, such as navigation and location-based activities. Recent technological enhancements in digital compasses (as well as gyroscopes) have seen the introduction of new products encompassing six-axis compass modules combined with an accelerometer. The higher precision and stabilizing effects achieved by these sensors lead to improved performance. In military and medical environments, where this is crucial, a new sensor has come to market that comprises a tri-axis gyroscope, a tri-axis accelerometer, a tri-axis magnetometer and a pressure sensor. We expect these sensors to coexist in the mobile market in the near term rather than replace each other as, in combination, they benefit each other.

User Advice:

- We expect the use of pedestrian navigation, and facilities for finding points of interest, to increase significantly during the next few years.
- Device vendors with a GPS strategy should implement digital compasses, because these can be strong differentiators due to improved user experience.
- Developers will expect this technology as a standard API for any smartphone platform.

Business Impact:

- The uptake of this technology is closely linked to the rapid increase of GPS in mobile handsets.
- An embedded compass makes a significant difference to pedestrian navigation. It makes reading and using digital maps more intuitive, because the maps rotate as the user moves.
- The primary impact will be on consumers, who will use pedestrian navigation to explore new areas and cities.
- The technology will also affect workers who rely heavily on navigation to do their jobs.

Benefit Rating: High

Market Penetration: 5% to 20% of target audience

Maturity: Adolescent

Sample Vendors: Apple; HTC; Memsic; Nokia; Research In Motion; Samsung

VoIP Over WLAN

Analysis By: Tim Zimmerman

Definition: This technology enables voice over Internet Protocol (VoIP) calls to be made over wireless LANs (WLANs).

Position and Adoption Speed Justification: VoIP over WLAN (VoWLAN) can be used by enterprises to seamlessly transfer calls from mobile networks to gateways that use the enterprise PBX. This solution has also been referred to as fixed-mobile convergence (FMC). Compared with earlier Wi-Fi networks, both 802.11g and 802.11n provide higher bandwidth for VoWLAN, and vendors are making investments to address the latency issue, which will improve enterprise VoWLAN quality and reliability.

Adoption of VoWLAN is helped by the increasing availability of VoIP soft clients dedicated to Wi-Fi-capable phones. As a result of competitive pressure and customer demand, VoWLAN also has support from mobile carriers that have, in the past, resisted supporting it. Due to the heavy traffic loads associated with the use of smartphones and third-generation (3G)/fourth-generation (4G)-enabled laptops and tablets, mobile carriers are encouraging users to use Wi-Fi to offload the traffic from the cellular network. This also encourages enterprises to employ VoIP over the Wi-Fi network.

We don't expect VoWLAN to present an immediate threat to mobile carriers' voice revenue in the short term, because large voice bundles have driven down the cost per minute for domestic calls, and VoIP is primarily used for international calls and intercarrier roaming. However, VoWLAN encourages employees to use more (multimodal) smartphones in the enterprise, at the expense of SIP/H.323 and legacy desk phones. This will erode the fixed-line voice revenue for carriers.

User Advice: Enterprises should look at VoWLAN as a part of the FMC capability, which is part of an enterprise's unified communications (UC) and wireless strategies. Enterprises should be aware of the minimum hardware support (e.g., codec) in the mobile client, to ensure the required mean opinion score (MOS)/Rating Factor (R-Factor) score, as well as the latency issues in the wired and wireless network that may affect the end-user experience.

Business Impact: Enterprises that abandon cabling to the desktop will use VoWLAN as part of an all-wireless office in small, medium, remote and branch offices. While VoIP/UC functionality provided by an on-premises, hosted or cloud-based voice function will always be required, this capability will eliminate the deployment of handsets to younger employees, who already use their smartphones as their home phones and will also use them as their desk/office phones.

Benefit Rating: Low

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Alcatel-Lucent; Apple; Avaya; Cisco; fring; Nokia; ShoreTel

Consumer Telematics

Analysis By: Thilo Koslowski

Definition: Consumer telematics represents end-user-targeted, vehicle-centric information and communication technologies (vehicle ICTs) and services that use embedded technology or mobile and aftermarket devices. Network-enabled cars for consumers provide in-vehicle services such as emergency assistance, navigation and routing, traffic information, local search (for example, for charging stations or restaurants), financial services (for example, usage-based insurance) and concierge services.

Position and Adoption Speed Justification: As a result of growing consumer demand for telematics and vehicle ICT, automakers are increasingly exploring opportunities to offer cost-effective solutions that ensure sustainable business models without substantial upfront investments. Rather than having to develop the required technology (that is, communications hardware) and resource infrastructure (that is, call centers) in-house, automotive companies are looking to engage third-party providers with comprehensive offerings that will take over the development, management and billing of vehicle-centric services. In addition, companies are looking for automated, Web-based services that leverage online or server-based information and make it accessible in a vehicle.

During the next two years, the supply chain for vehicle ICT offerings will change and will focus on extending existing mobile applications and services (from the mobile and Internet services industries) to vehicles, in addition to creating specific automotive functions (for example, expanding existing application ecosystems, such as those based on Android applications, to the vehicle). Telematics service providers (TSPs) will face competition from new companies that will aggregate other third-party wireless content and develop core technological value propositions from a mobile device perspective. These companies include smaller software, hardware and content providers that target specific aspects of a holistic consumer telematics application and work closely with automakers or system integrators to ensure compatibility and reliability. Consumer telematics is also increasingly developed for the automotive aftermarket by TSPs and insurance providers. In mature automotive markets such as the United States and Western Europe, most manufacturers will offer consumer telematics in virtually all of their models by 2020 due to long product development cycle times. In emerging automotive markets, this milestone may occur slightly later.

User Advice: As telematics services, applications, technology and content providers emerge, vehicle and device manufacturers (for example, consumer electronics companies) will have to choose the providers that best fit their business and technology requirements. Companies wanting to offer connected vehicle services to consumers should take advantage of the emerging offerings in the mobile- and location-based service space. The market is becoming more mature, and vendors have made significant investments in building the expertise, resources and partnerships that can help companies accelerate their vehicle ICT launches. Furthermore, vehicle manufacturers and device manufacturers must differentiate between core, vehicle-centric telematics offerings that are embedded in a vehicle (most safety and security applications) and personal telematics offerings (primarily information and entertainment services), which consumers access by integrating portable devices with the vehicle.

To enable device-to-vehicle and service-to-vehicle integration concepts, vehicle manufacturers must collaborate with consumer electronics companies, service and content providers (regarding interfaces), and connectivity solutions. The introduction of electric vehicles (EVs) will give consumer telematics a boost because seamless EV ownership experiences will greatly benefit from connected data services (for example, finding the next charging station and informing drivers of the available range left).

Consider your choices in a growing vendor supply chain by identifying best-of-breed technology providers instead of a single-solution approach. Both options have their benefits and disadvantages, but with increasing in-house expertise for the connected vehicle, automotive companies can be more selective in their partner choices to better balance innovation and cost objectivity factors (for example, innovation within connected vehicle offerings should reside with the automakers).

Business Impact: Consumer telematics provides an opportunity to differentiate product and brand values (for example, infotainment access and human-machine interface experience), to create new revenue sources (subscriptions and mobile commerce), to collect vehicle-related quality and warranty information via remote diagnostics, and to capture consumer insights.

Benefit Rating: High

Market Penetration: 20% to 50% of target audience

Maturity: Adolescent

Sample Vendors: Agero; Airbiquity; Google; Hughes Telematics; Microsoft; Nokia; OnStar; WirelessCar

Recommended Reading: "OnStar Anywhere Brings Telematics Service to All Auto Brands"

"U.S. Consumers Put Vehicle ICT Back on Their Wish Lists, but Feature Priorities Are Changing"

"OnStar Selects Android to Expand Its Ecosystem"

Phone-as-a-Token Authentication Methods

Analysis By: Ant Allan

Definition: Phone-as-a-token authentication methods are those that make use of a mobile phone as an authentication token. The two most popular examples are:

- Out-of-band (OOB) authentication, in which user and authentication server exchange authentication information over a different channel from the one between endpoint and server. Typically, these methods exploit automated voice calls or SMS text messaging.
- One-time password (OTP) software tokens for smartphones; apps that allow phones to be used like traditional OTP hardware tokens.

Position and Adoption Speed Justification: Phone-as-a-token authentication methods leverage tokens that users likely already possess and offer a lower total cost of ownership (TCO) and better user experience (UX) than OTP hardware tokens. Adoption of phone-as-a-token authentication methods has continued to increase over the past year and, while there is still a huge installed base of OTP hardware tokens, phone-as-a-token authentication methods are now clearly more popular in new or refreshed deployments.

During the past few years, many banks have implemented OOB authentication for online retail banking and many enterprises have implemented OOB authentication for workforce remote access. In the latter case, this is often for lower-risk access (such as workforce self-service portals) or for contingent use (for example, enabling secure remote access for all in a business continuity context), but some enterprises are using it as a full substitute for OTP hardware tokens for remote access to the corporate network via a VPN or hosted virtual desktop (HVD).

OTP software tokens for mobile phones are less popular in online banking, but enterprises tend to prefer them for users with time-critical remote access needs, because OOB authentication methods can be vulnerable to poor cellular network coverage, availability and (for SMS modes) latency problems. Some vendors are driving adoption by offering zero-cost OTP software tokens (which still require licensed authentication infrastructure software or services, however).

Despite its success to date, the longer-term future of phone-as-a-token authentication methods will be hit by the rise in mobile computing in two ways:

- First, the assurance provided by a phone as a token can be eroded when the phone itself (rather than the user's PC) is the endpoint, and we note that a few regulations explicitly require tokens to be separate from the endpoint (for example, the DEA interim final rule that mandates the use of "two-factor authentication credentials" for practitioners who sign electronic prescriptions; see "Good Authentication Choices for Healthcare Delivery Organizations").
- Second, mobile computing can degrade the user experience (UX) or break the method altogether. It's awkward for a user to swap between the mobile browser or a custom app and the authentication app, whether an OTP app, SMS app or voice call (although several vendors provide SDKs that allow OTP generation to be built into custom apps). Furthermore, not all phones allow use of the voice channel when the data channel is being used.

To address these issues, enterprises will seek an additional or alternative method that can provide higher assurance with better UX. Gartner predicts that biometric authentication is likely to be the most popular candidate (see "Predicts 2012: A Maturing Competitive Landscape Brings New IAM Opportunities" and "Q&A: Biometric Authentication Methods").

Nevertheless, productive use of phone-as-a-token authentication methods in many use cases, especially where PCs or tablets are the preferred endpoint, will continue to grow in the short to midterm, with adoption by 20% to 50% of the market within the next few years.

User Advice: The popular phone-as-a-token authentication methods are a viable alternative to traditional hardware tokens across several use cases. However, as for any authentication method, an enterprise must evaluate the potential benefits against the needs of each use case (see "How to

Choose New Authentication Methods"), and choose among the options on the same basis. Furthermore, any authentication method can be defeated or bypassed, and the best defense against many attacks is to implement a layered fraud prevention approach (see "The Five Layers of Fraud Prevention and Using them to Beat Malware").

Phone-as-a-token authentication methods have two significant advantages over OTP hardware tokens, X.509 smart tokens and the like:

- Lower TCO: They typically cost less than dedicated devices (see "How Much Is That Token In the Window? What You Should Expect to Pay for New Authentication Methods") and eliminate distribution costs, which can be more than the cost of the devices themselves. (There are still registration costs, however.)
- Improved UX: End users do not have to remember to carry a dedicated device (and will tend to take more care of a phone, improving security). Furthermore, a single phone can support OOB authentication and OTP software tokens from multiple organizations, giving the user only one device to carry.

OOB authentication may be charged either per user, per year or per transaction, depending on the vendor, with a per-transaction pricing model generally being more advantageous for low-volume users. OOB authentication to a mobile phone depends critically on network coverage, availability and (for SMS modes) network latency (although some vendors can address these issues).

SMS modes are more widely used in Europe and Asia/Pacific, given the popularity of SMS support in those regions (while voice modes are more popular in North America). Some users may have concerns about costs or liabilities and may reject unexpected SMS messages as spam.

While OOB authentication using voice modes is often more expensive than that using SMS, it is generally more reliable (no latency), provides better forensics (call logging), can capture a recording of the user's voice for nonrepudiation and forensic purposes, or incorporate biometric voice recognition for higher levels of assurance and accountability.

In general, OOB authentication provides only a medium level of assurance: NIST SP 800-63-1 "Electronic Authentication Guidelines," for example, ranks OOB authentication, used in conjunction with a password, at Level 3, while it ranks PIN-protected OTP hardware tokens at Level 4 (higher). We have seen successful attacks against OOB authentication in online banking. A risk with voice calls is that they can be illegitimately forwarded to unauthorized users' phones, although some vendors can use SS7 data to identify when this happens.

OTP software tokens offer a more robust solution than OOB authentication alone, approaching the reliability and level of assurance of OTP hardware tokens (although they are not explicitly ranked by NIST SP 800-63-1), and so suit higher-value access. However, users require a suitable smartphone (most vendors support all popular mobile OSs), which not everyone will have. Depending on vendors' pricing schemes and usage volumes, the TCO for OTP software tokens may be higher or lower than for OOB authentication. Enterprises must take into account the cost of over-the-air provisioning, registration and personalization, likely for multiple mobile OSs.

As noted earlier, phone-as-a-token authentication methods are less well-suited to use cases where the phone itself is the endpoint. An enterprise must weigh the limitations of these methods against the uncertainty of what the best-practice approach will be. While Gartner predicts that biometric authentication is likely to be the most popular candidate in the mid to long term, this is still not widely supported or adopted, and many enterprises are exploring other alternatives, such as X.509 software tokens (see "Digital Certificates Can Be a Good Alternative to OTP Hardware Tokens for Smartphone Authentication"), in the short term.

Furthermore, it seems likely that enterprises will be unwilling to support (and users unwilling to put up with) different authentication methods for use with different endpoints in the mid to long term, so the best solution for use with smartphones is likely one that can most easily be adopted for use with PCs and tablets as well (again, biometric authentication methods are likely to be preferred; see the discussion of biometric authentication methods in "Hype Cycle for Identity and Access Management, 2012"). Thus phone-as-a-token authentication methods will be superseded altogether on this time scale (although they may already have reached the Plateau of Productivity by then).

Business Impact: Phone-as-a-token authentication methods provide authentication in a form that is independent of any particular PC or PC OS, at a lower cost than traditional OTP tokens, and with greater convenience for the user. Phone-as-a-token methods can also improve security, as users will generally take more care of their phones and will be less likely to share them with colleagues. Like OTP tokens, they enable user mobility and avoid the difficulties with remote technical support that X.509 smart tokens can run into. Furthermore, these methods help with "green" IT initiatives because they avoid the need for further devices that will have an environmental impact.

While the uptake of mobile computing will limit the usefulness of phone-as-a-token authentication methods in the long term, they remain a viable choice in the short to midterm.

Some phone-as-a-token authentication methods can provide additional value through transaction verification via the same mechanism (see "Q&A: Phone-Based Authentication Methods" and "Transaction Verification Complements Fraud Detection and Stronger Authentication"). This additional capability is not reflected in the benefit rating here: In situations where transaction verification is pertinent, the rating for combined phone-as-a-token authentication and transaction verification may be high.

Benefit Rating: Moderate

Market Penetration: 5% to 20% of target audience

Maturity: Early mainstream

Sample Vendors: Authentify; Entrust; Equifax; Mideye; PhoneFactor; RSA, The Security Division of EMC; SecurEnvoy; SMS Passcode; Symantec; Technology Nexus; TeleSign; ValidSoft

Recommended Reading: "Digital Certificates Can Be a Good Alternative to OTP Hardware Tokens for Smartphone Authentication"

"A Taxonomy of Authentication Methods, Update"

"The Five Layers of Fraud Prevention and Using them to Beat Malware"

"How Much Is That Token In the Window? What You Can Expect to Pay for New Authentication Methods"

"Q&A: Phone-Based Authentication Methods"

"Where Strong Authentication Fails and What You Can Do About It"

"How to Choose New Authentication Methods"

"Transaction Verification Complements Fraud Detection and Stronger Authentication"

Off the Hype Cycle

Mobile Browsers

Analysis By: Hugues J. De La Vergne; Michael Gartenberg

Definition: The mobile browser is an on-device, client-side application. It provides access to content and applications from the Internet and in the cloud. Desktop and mobile browsers share many functions; however, increasingly, there are also differences, including the size of the screen, the power of the device (both processor and memory footprint), the speed of the network and the resources on the device. The browser for a mobile device has been considered a lower-functioning device than the browsers found on the desktop, but the gap is decreasing.

Position and Adoption Speed Justification: Although browsers on mobile phones, in general, are relatively mature, the technology has been poorly adopted, because of the user experience it delivered. This has been exacerbated by inconsistent implementation of browser standards by the big smartphone vendors, which is also the reason this technology has moved backward on the Hype Cycle. During the next three years — with the adoption of HTML5 by many of the browsers and the standardization of resource (such as location, camera and accelerometer) access on smartphones — the adoption of mobile browsers for application access and content delivery will increase dramatically. (HTML5 enables significant offline caching of information for application functionality without a network connection, among other things.) The separation between the capabilities of the HTML5 browsers shipped on the devices and the standardization of interfaces, in terms of timing and delivery, will be a gating factor for cross-platform requirements.

Three categories of mobile browsers are supported across a variety of devices:

- Fully functional, HTML5-compliant, webkit-capable browsers — These are often found on smartphones and devices with OSs, such as BlackBerry (Research In Motion [RIM]), OS X (Apple) and Android. Most tablets support these types of browsers as well, although we envision most of them moving to desktop-derived browsers during the next two to three years.
- Middle-function browsers, with HTML and graphics support, but limited support for advanced feature sets or access to resources on the device — These are found on older versions of RIM OSs, Symbian devices and third-party support.

- Wireless Application Protocol and limited-function, text-based browsers — These are often found on feature phones.

The highly variable target for content and Web developers means that fewer than 20% of mobile applications developed are thin-client (or browser-based). With the adoption of HTML5 and the capabilities it provides, Gartner sees that percentage moving toward 40% to 50% during the next three years, particularly for informational or form-based applications.

User Advice: Enterprises should experiment with thin-client (browser-delivered) application design and content delivery for their end users and customers. Although standardized HTML5 implementations in the context of a mobile browser are likely to be three to five years out, the security and information delivery capabilities of mobile browsers may be an appropriate fit for a growing number of mobile application initiatives.

Business Impact: The impact of the browser is threefold:

- For mobile device and platform vendors, the browser experience is a way to differentiate their products and entice a wider range of content owners to enable access via the mobile device.
- For content owners and application developers, the browser offers a secure, and increasingly rich, way to deliver a wide range of content types and is another architecture to consider for that delivery.
- For enterprises, the mobilization of information will enable employees to depend less on device types and requirements of those individual platforms.

Benefit Rating: High

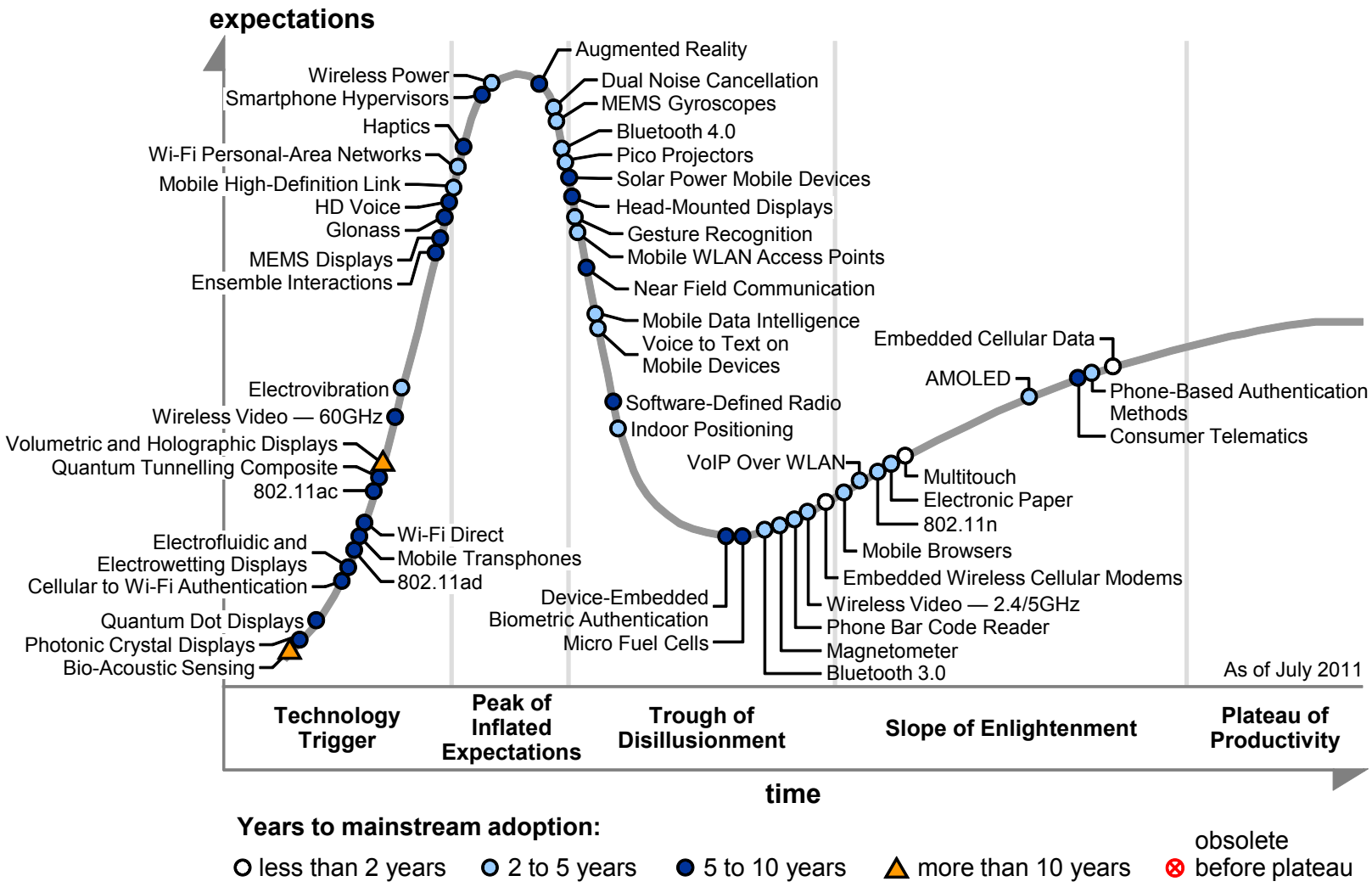
Market Penetration: More than 50% of target audience

Maturity: Off the Hype Cycle

Sample Vendors: Apple; Google; Nokia; Openwave Systems; Opera; Research In Motion

Appendixes

Figure 3. Hype Cycle for Mobile Device Technologies, 2011



Source: Gartner (July 2011)

Hype Cycle Phases, Benefit Ratings and Maturity Levels

Table 1. Hype Cycle Phases

Phase	Definition
Technology Trigger	A breakthrough, public demonstration, product launch or other event that generates significant press and industry interest.
Peak of Inflated Expectations	During this phase of overenthusiasm and unrealistic projections, a flurry of well-publicized activity by technology leaders results in some successes, but more failures, as the technology is pushed to its limits. The only enterprises making money are conference organizers and magazine publishers.
Trough of Disillusionment	Because the technology does not live up to its overinflated expectations, it rapidly becomes unfashionable. Media interest wanes, except for a few cautionary tales.
Slope of Enlightenment	Focused experimentation and solid hard work by an increasingly diverse range of organizations lead to a true understanding of the technology's applicability, risks and benefits. Commercial off-the-shelf methodologies and tools ease the development process.
Plateau of Productivity	The real-world benefits of the technology are demonstrated and accepted. Tools and methodologies are increasingly stable as they enter their second and third generations. Growing numbers of organizations feel comfortable with the reduced level of risk; the rapid growth phase of adoption begins. Approximately 20% of the technology's target audience has adopted or is adopting the technology as it enters this phase.
Years to Mainstream Adoption	The time required for the technology to reach the Plateau of Productivity.

Source: Gartner (July 2012)

Table 2. Benefit Ratings

Benefit Rating	Definition
Transformational	Enables new ways of doing business across industries that will result in major shifts in industry dynamics
High	Enables new ways of performing horizontal or vertical processes that will result in significantly increased revenue or cost savings for an enterprise
Moderate	Provides incremental improvements to established processes that will result in increased revenue or cost savings for an enterprise
Low	Slightly improves processes (for example, improved user experience) that will be difficult to translate into increased revenue or cost savings

Source: Gartner (July 2012)

Table 3. Maturity Levels

Maturity Level	Status	Products/Vendors
Embryonic	▪ In labs	▪ None
Emerging	▪ Commercialization by vendors Pilots and deployments by industry leaders	▪ First generation High price Much customization
Adolescent	▪ Maturing technology capabilities and process understanding Uptake beyond early adopters	▪ Second generation Less customization
Early mainstream	▪ Proven technology Vendors, technology and adoption rapidly evolving	▪ Third generation More out of box Methodologies
Mature mainstream	▪ Robust technology Not much evolution in vendors or technology	▪ Several dominant vendors
Legacy	▪ Not appropriate for new developments Cost of migration constrains replacement	▪ Maintenance revenue focus
Obsolete	▪ Rarely used	▪ Used/resale market only

Source: Gartner (July 2012)

Recommended Reading

Some documents may not be available as part of your current Gartner subscription.

"Understanding Gartner's Hype Cycles, 2012"

"Competitive Landscape: Connected Handheld Gaming Devices"

"Contextual Smartphone Applications Will Exploit Augmented Reality"

"Emerging Technology Analysis: Augmented Reality Shows What Mobile Devices Can Do"

"Emerging Technology Analysis: MEMS Displays Cut Mobile Device Power Consumption"

"Emerging Technology Analysis: Voice-to-Text on Mobile Devices"

"Forecast: Consumer Location-Based Services, Worldwide, 2008-2014"

"Forecast: Connected Mobile Consumer Electronics, Worldwide, 2008-2015, 1Q11 Update"

"Forecast: Mobile Devices, Worldwide, 2008-2015, 1Q11 Update"

"Cool Vendors in Consumer Devices, 2011"

This is part of a set of related research. See the following for an overview:

- Gartner's Hype Cycle Special Report for 2012

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