Travels with iPad Maps

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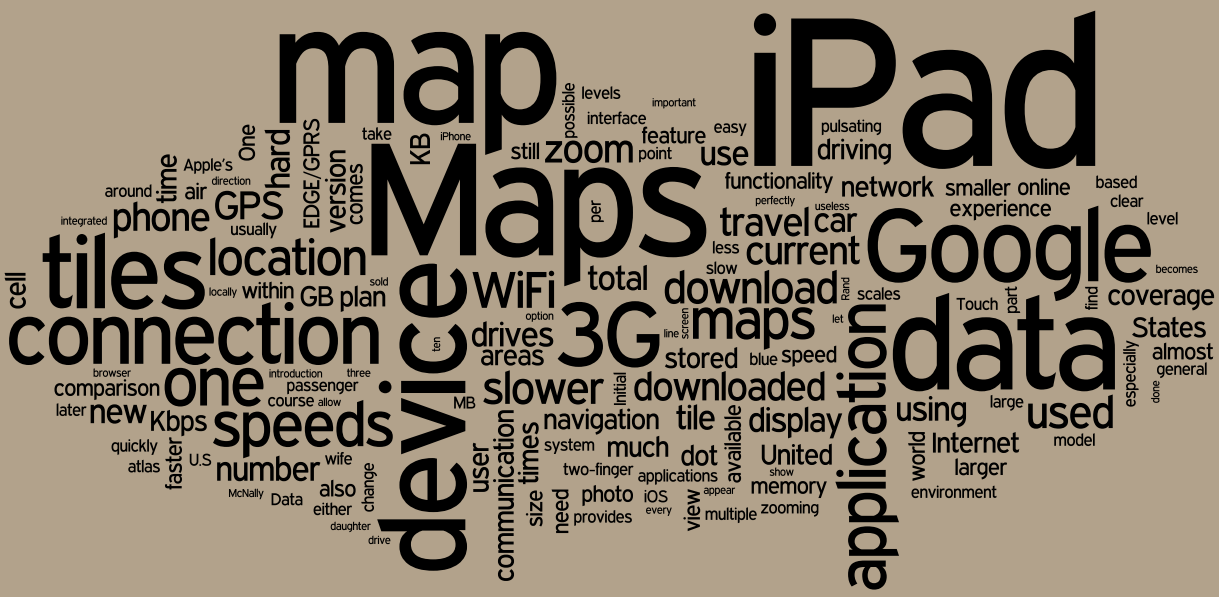

The iPad is a larger version of Apple's iPod Touch, a non-phone version of the Apple's hugely popular iPhone. Inside the iPad is a circuit board the size of the iPhone/iPod Touch and large battery to power the 9.7", 1024 x 768 pixel screen. The iPhone, iPod Touch, and the iPad share the same iOS operating system. Two models of the iPad were introduced in April 2010. One version communicates only through WiFi while the second includes the possibility of a 3G cellular data connection. Initially, the iPad was limited to AT&T. The least-expensive data plan through AT&T is $15 a month for a maximum of 250 MB. A $30 plan initially provided unlimited data download, but was changed to a $25 option with a 2 GB maximum within a matter of weeks after the introduction of the original iPad. The iPad 2, with a faster processor and front and back cameras, was released in March 2011. The new version has the same display size and resolution as the original model. The user now has a choice of a 3G connection through Verizon.

Reviewed here is the Maps application that comes with Apple's iPad. Maps is essentially a stand-alone implementation of Google Maps and is available on all three iOS platforms. Normally, Google Maps would be accessed through a browser, and this is still possible through iPad's integrated Safari application. The Maps application provides a direct connection to Google Maps with an improved user interface, although there is some reduction in functionality. For example, it is not possible within the Maps application to change a calculated route by clicking and

dragging a line to a new location. In exchange for this loss in functionality, the two-finger zoom function is cleanly implemented to quickly change the scale of the map.

The most important feature of iPad Maps is the close integration with the GPS, Wi-Fi, and/or cell tower triangulation location-finding abilities of the device to show the current location. This is symbolized with a pulsating blue dot and a surrounding circle that becomes smaller as the positioning becomes more accurate—a form of data uncertainty symbolization.

The question addressed here is how iPad Maps works as a navigation device and as a general travel companion. It should be made clear that the iPad is not sold as a navigation device. While car mounts are available for the iPad that would allow the driver to view the map while driving, evaluation of the Maps application was always done by a passenger. The Maps application that comes with the iPad requires considerable attention and should not be operated while driving. Separate applications are available for an extra fee that would allow hands-free navigation using the iPad, but these were not tested.

The 32GB, WiFi+3G iPad that I ordered was shipped directly from Shanghai, China, and arrived at the beginning of May 2010. It connected to WiFi immediately upon startup. Once on WiFi, the 250 MB monthly 3G connection was easy to purchase from AT&T. Testing was done with iPad Maps over a four-month period in which approximately 10,000 miles were logged. All driving was within the United States and stretched from the states of New York to California.

To put this evaluation in context, let me divulge that I am usually not an early adopter. I still don't have my own cell phone. My wife has a four-year old Motorola flip-up model with none of the fancy features of the modern, status-symbol smart phone. Talking to my daughter recently, I was puzzled by the strange beeps that I heard. My daughter informed me in a patient but quizzical voice that younger people reserve for the old that I was getting another call and told me what I needed to do to answer it.

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The almost ubiquitous GPS navigation device has also not infiltrated our car. We experienced GPS-assisted navigation in car rentals in both Japan and Germany and were less than impressed. The glorified arrow that substitutes for a map display did not help me form a mental map of the environment, or provide a sense of well-being that comes from knowing where you are and what's around. My German helped me comprehend the instructions offered by the device in Germany, and it did help us find places, but the Japanese model spewed an indecipherable litany of instructions, none of which I understood. The Japanese have implemented an interesting system that allows the GPS device to find a location based on a phone number of the destination. Having no idea how to input a phone number, I stopped at a gas station and a gentleman there was more than happy to enter the phone number with the included remote control. The in-dash GPS then led us through the night to the isolated hotel in the mountains using straight, left and right arrows and the reassuring dot moving along a random line. At that point, I didn't much care about the sense of well-being that comes from knowing what's around.

INITIAL EVALUATION OF THE iPAD FOR NAVIGATION

Initial impressions of the device varied based on the person using it. When I was driving, the passenger was usually my wife, who is perfectly comfortable with paper maps. I had purposely tucked our battered travel atlas away under the luggage, forcing her to use the iPad. She eventually adapted to the touch interface and two-finger zooming and appreciated the pulsating dot that would show our current position. Also attractive was zooming, and the ability of the device to find a location, plot a route, and determine the travel time. This was especially useful within cities where the Maps application could be used to quickly change between map scales. But, being a map user who orients the map in the direction of travel, my wife was disappointed when she tried rotating iPad Maps in a similar way. With the integrated accelerometer, the iPad dutifully re-oriented the map to the north no matter in which direction the device was turned. She concluded that the device was "designed by men" (a switch on the side of the iPad stops the re-orienting feature).

The single, major limitation of the iPad for travel is the speed of data communciation

Everyone used the device differently. Our grown children reached for the device immediately upon entering the car. They would use the Safari browser to check a webpage, or to chat. The Maps application was used only when necessary.

When I was a passenger, I kept Maps open—switching often to the "Satellite" view and comparing the countryside to the view from above. Traveling with a complete set of air photos and having them appear automatically as one moved through the environment was a new experience. Anyone with a geography background would appreciate this feature and the device should be a part of any course in air photo interpretation or remote sensing.

I later had the opportunity to take students on a field trip using the iPad. Seeing the current location clearly indicated on an air photo while walking through the environment was also new to them. The experience made it easy to interpret every feature depicted on the photo. Of course, this was much easier standing in the shade. It is almost impossible to use the iPad in direct sunlight.

SPEED OF DATA COMMUNICATION

The single, major limitation of the iPad for travel is the speed of data communication. AT&T's 3G network only covers a small part of the United States (blue shading in Figure 1). Further, while 3G is capable of download speeds up to 1.75 MB/s, this speed was never achieved in real-world testing. AT&T implements a much slower EDGE/GPRS data communication network in much of the United States (orange shading in Figure 1). The EDGE/GPRS network is rated at speeds of between 75–384 Kbps, 23 times slower than 3G. Most of the United States either has no AT&T coverage or a much slower "Partner EDGE/GPRS" data connection at only 75–388 Kbps.

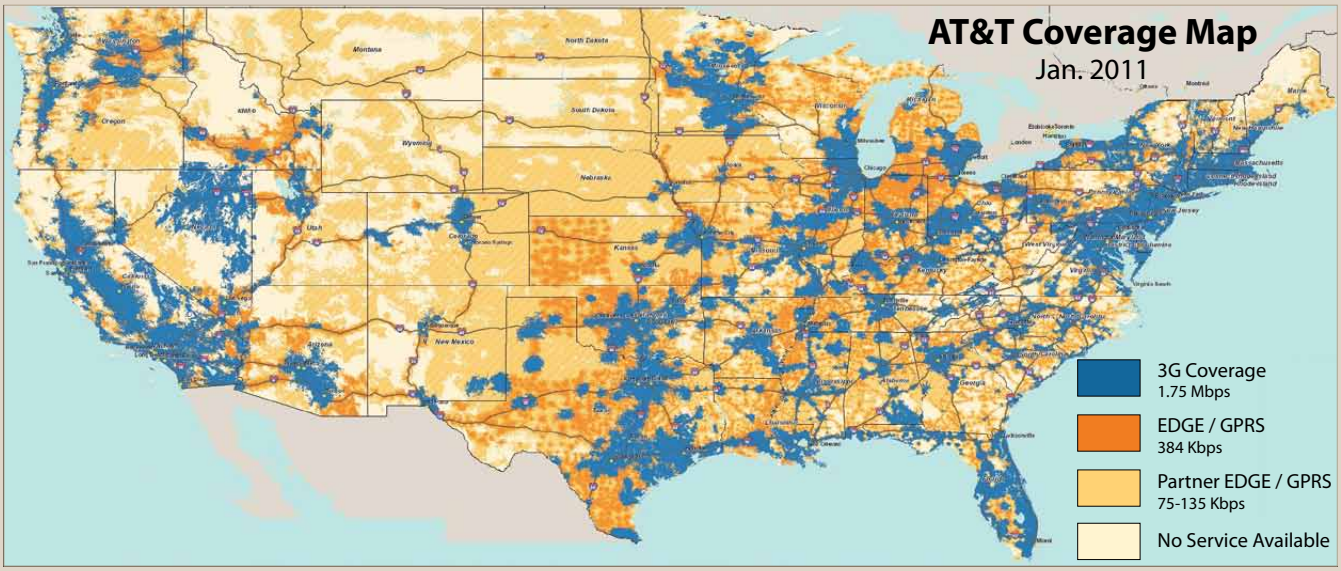

Figure 1. AT&T Coverage Map. Only a small part of the U.S. by area has access to 3G data communication. The company claims coverage for 230 out of the total 307 million population. Rural areas have very poor coverage.

Download speeds vary based on distance from the cell site, general load on the network, intermediate links to the core network, and a host of other factors.

Often, especially in areas not covered by 3G (most of the United States) and at larger scales, the Maps application could only present a blue pulsating dot against a blank background. Zooming out would give the option of a small-scale map because very little updating is required to keep up with any kind of movement. But, at larger scales and especially when traveling by car, the map would need to move forward faster than the capability of the device to download the map or the photo. At that point, one realizes the importance of the map. Without the map, the moving dot that indicates the current location is meaningless. One also realizes the importance of a fast data connection. As one user stated about the iPad: "This thing is useless without 3G."

Google Maps is a tile-based online mapping system. Image tiling had been used since the early days of the web, but was only applied to maps with the introduction in 2005 of Google Maps. Now, all major online map providers use the tile-based approach. In comparison to text, images always take longer to download. The tiling solution divides the image into smaller segments, or tiles, and sends each tile individually through the Internet. These smaller files take different routes to their destination, and are subsequently placed in their proper location on the receiving end. All of this occurs so quickly that the user rarely notices that the image is composed of pieces.

With a non-3G cell phone connection to the Internet, it is painfully obvious that the map is composed of tiles. Data transfer is so slow that one can see the tiles appear, usually one by one. Once downloaded, the tiles are stored locally for some time, making the paning and zooming process almost instantaneous. However, the initial wait for the tiles to download makes the Maps application essentially useless when driving in rural areas. Once the tiles have been downloaded, the car is well beyond that part of the map. Through

experimentation, it was later determined that the Maps application caches a large number of map tiles. It is thus possible to download a map before traveling when a higher data communication speeds are available, either by WiFi or 3G.

The total number of bytes that need to be downloaded for one map display can easily be estimated. Each map tile is 256 x 256 pixels and the iPad has a display size of 1024 x 768 pixels. If the point of interest (POI) falls perfectly in the middle, the device needs four tiles in one dimension by three tiles in the other, for a total of 15. More tiles would be downloaded if the POI is not in the middle of a tile. Each tile is stored in the PNG format and they average around 20 KB each for land areas. That means that one iPad map display would be about 300 KB.

At 300 KB per map, one might wonder how many screen-sized maps can be downloaded under the two data plans. For the $15/250 MB plan, one could download approximately 83 screen displays – about 18 cents a map. For the $25/2GB data plan, one would get 667 maps at about 3.7 cents a map. In comparison, a Rand McNally road atlas is less than $10 and the maps can be used multiple times. Maps for the iPad need to be re-loaded almost every time they are used. Rand McNally would surely accept $25 a month for their atlas, rather than $15 for the one-time sale.

LOD	Number of tiles	Distance on the ground in meters for each pixel
1	4	78,272
2	16	39,136
3	64	19,568
4	256	9,784
5	1,204	4,892
6	4,096	2,446
7	16,384	1,223
8	65,536	611
9	262,144	306
10	1,048,576	153
11	4,194,304	76
12	16,777,216	38
13	67,108,864	19
14	268,435,456	10
15	1,073,741,824	5
16	4,294,967,296	2
17	17,179,869,184	1
18	68,719,476,736	0.60
19	274,877,906,944	0.30

Table 1. The number of tiles used by Google Maps to represent the world at 19 different levels of detail (LODs), and the corresponding distance on the ground represented by each pixel at the equator.

In case you are wondering if the Google Map tiles could simply be stored locally on the iPad, let us examine the size of the entire Google Maps database. Table 1 shows the number of tiles that Google uses for the 19 different levels of detail that Google provides. At the 19th zoom level, there are over 274 billion tiles to represent the entire world. At an average of 15 KB per tile (tiles for ocean areas are only 10 KB), a map of the world would require 3,932,160 GB, or 3,840 Terabytes, or 3.75 Petabytes.

The U.S. represents about 6.5% of the total world area, so we would only need to store 255,590.4 GB, or 246 TB. Using traditional hard drive technology, a map of the U.S. could be stored

with a total of 123, 2 TB hard drives at about $100 piece, for a total of $12,300. If using smaller flash drives, eight times as many 256 GB drives could be used at a cost of $400 a piece for a total of $393,600.

Rather than using slower hard or flash drives, there is some indication that Google stores the Google Map at its data centers in RAM for faster access. At current memory prices of $36 per GB, this would cost Google $141,312,000 for each data center, and Google has multiple data centers. It is likely that Google stores only the most commonly requested tiles in RAM while the remaining tiles are stored on hard drives.

It should be noted that these calculations are only for the 19th zoom level. Smaller but still significant amounts of hard drive space or memory would be needed for the other zoom levels. In addition, Google has added a 20th zoom level for some areas of the world. While Google is in a better position to negotiate on the prices of hard drives and memory, it is clear that they have invested a large amount of money in Google Maps. If anyone asks who thinks maps are important, it is clear that Google does.

Trial	EDGE Download	EDGE Upload	3G Download	3G Upload	WiFi Download	WiFi Upload
1	48	73	1662	187	10639	6251
2	107	31	1549	189	10318	6197
3	82	4	1168	93	10719	5856
4	22	15	1191	93	10544	5076
5	148	43	969	95	11021	5352
6	99	0	1181	97	10404	6290
7	96	76	1292	177	11096	6676
8	163	36	1045	97	10876	7266
9	83	34	947	96	10889	6713
10	98	34	1737	188	11470	6865
Average	**94.6 kbps**	**34.6 kbps**	**1274.1 kbps**	**131.2 kbps**	**10797.6 kbps**	**6254.2 kbps**

Table 2. iPad speed comparison between AT&T 3G, AT&T EDGE and WiFi. A total of 12 trials were taken. The fastest and slowest download speeds were deleted.

In the end, as with most things related to the Internet, the iPad as a travel companion is only as good as the speed of the data connection. Table 2 shows the comparison in download and upload speeds for ten time trials between EDGE, 3G, and WiFi on the iPad, as measured with SpeedTest.net. In general, real-world EDGE speeds were about 10 times slower than 3G, and 3G is 8.5 times slower than WiFi. WiFi speeds are related to the speed of the Internet connection with the Internet Service Provider.

CONCLUSION

For portability and interactivity in map use, iPad and Maps is an amazing combination. Of course, a similar experience of navigating with an online map and GPS could be emulated with a notebook computer, an attached GPS device, and a data plan from a cell phone company. iPad Maps integrates all of this in a sleek ½" thick, 1.6 lb device. The two-finger interface is also easy to learn and the GPS integration is effortless. With a 3G data connection, the device will instantly tell you where you are. It may require some patience, but the iPad will tell you where you are going and how to get there. The Satellite view, normally a series of air photos that are stitched together, provides a new and unparalleled travel experience.

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The most disappointing aspect of the device is the slowness of AT&T's data communication. The company's 3G coverage is minimal, covering only the larger cities. Most of the U.S. either has no coverage, or a slower EDGE/GPRS data communication with rated speeds between 75–384 Kbps. Real-world speeds for this data connection were only between 22–163 Kbps in ten time trials. In comparison to WiFi at more than 10 Mbps (10,000 Kbps), these speeds are extremely slow. Initial reports indicate that Verizon has slower 3G connection speeds but the area coverage is greater.

Data connection coverage problems can be partially avoided by viewing the maps (and images) while still connected through WiFi or 3G. The Maps application caches a certain amount of map tiles and can be used later even without a data connection. As long as all tiles for multiple zoom levels have been downloaded, the functionality of iPad Maps is the same. One can zoom in and out and the device indicates the current location. Any functionality that requires a data connection will continue to be painfully slow, such as determining the distance to a location.

The iPad is just the first of a new generation of Internet-enabled, slate computers. The popularity of these portable devices is evidenced by reports that Apple had sold 19 million by March 2011. One of the main applications of the device will be the display of maps. The use of online maps with these devices will become less frustrating with faster wireless data communications and better applications that store more of the downloaded maps in memory.

EPILOGUE

After the U.S. experience, the author had a chance to use the iPad while driving in three foreign countries: Costa Rica, France, and Ireland. The 3G connection was never activated. Replacing the internal SIM card so that the device would have connected through a local mobile provider would have been possible but was considered too difficult and expensive. Data plans are even more costly outside the U.S. Even without 3G, the Maps application proved to be a very useful travel companion.

Before traveling to Costa Rica, Maps was used to cache multiple scales of maps of the areas we planned to travel. Although Google does not have a very complete map of the country, the map was often better than the paper map we had purchased. WiFi was much more accessible in Europe and so the Google Maps application was used each evening to cache the maps that would be necessary for the following day. The maps for these countries are very complete, including the smallest of roads.

Although we only used WiFi for data transfer in our foreign travels, it is still important to obtain the 3G version of the iPad as this is the only model that is GPS-enabled.