5 DISCUSSION

As other studies showed, JSON responses are lighter and faster to download. They are thus better suited to mobile devices where data caps and slower mobile networks are real limitations. XML and GML suit situations where strict adherence to a schema is critical to process success.

The frequency distributions of response times are heavily skewed towards shorter timeframes. Regardless of the dimension studied ~~(~~for instance OGC versus Esri, XML versus JSON versus image data~~)~~ the bulk of response times fell within the same order of magnitude. The fact that ~~our~~ the charts need a logarithmic axis for response time to show the interquartile range indicates that Landgate's servers are suitable for the range of mobile situations investigated.

LandgateAPITest discovered only 79 reference check failures. This is, admittedly, a small sample set from which to draw conclusions on whether spatial servers return incorrect or incomplete data in specific circumstances. A few orders of magnitude more such errors could substantiate conclusions. Unfortunately, this would require more time and data download limit than this study has resources to allow.

The finding that failures are more frequent with increasing distance travelled is not an issue with Landgate's servers. Longer distances travelled during tests are an outcome of highway speed travel where the device is more likely to encounter signal interruptions or inferior signal strength.

According to this work, incorrect data is delivered only 0.6% of the time. If ~~we extend from this~~ finding, ~~we~~ it is extended can assume ~~that~~ be there are few situations where this would be a critical hindrance for a mobile device.

The OASIS web service quality standard (Kim et al., 2012) calls for calculation of Availability, Accessibility and Successability (among others). These are predicated on the assumption that the testing device is guaranteed access to the internet to perform its tests. In other words, the testing device is assumed to be infallible while the tested service is not. This is entirely possible to achieve in controlled conditions,

the testing machine simply does not send a request when it is not certain of success, or ignores tests where certain preconditions of controlled experiment are not met. The output then is a percentage of tests where the tester was able to contact the service, the difference from 100% being entirely the fault of the service.

LandgateAPITest's methodology does not assume as given nor control its connection to the internet. The application proceeds with a test so long as there is some connectivity, regardless of its reliability. A failed request which timed out (and hence received a "0" response code from the iOS application) could either be the fault of server downtime or lack of a mobile network connection on the device's part.

As such LandgateAPITest is not able to reliably determine Accessibility or Availability. These are common testing metrics and future versions should address this shortcoming.

Successability is similar in that LandgateAPITest cannot reliably determine whether the lack of a response to a request is the fault of the server or the network. However, the Oasis standard assumes WSDL responses are "error-free". LandgateAPITest again does not make this assumption and interrogates the response data for errors.

Overall LandgateAPITest is not an everyday testing suite. There are many suitable applications, as shown in the literature review, capable of determining such oft required statistics. This app more closely tests the mobile device user's experience with the data served by a geographic web service. Environmental factors of network connectivity, constrained device processing power and others have a larger effect on whether the service will successfully deliver data to meet the user's needs.

6 RECOMMENDATIONS

Esri ArcGIS Servers can provision OGC and KML web services alongside their Esri Rest services. Landgate has enabled WMS services for their Public ArcGIS MapServers, but not WFS or KML. Doing so would improve interoperability for open source apps such as QGIS at little incremental cost. Older infrastructure could then be decommissioned without reduced service to the community.

Esri JSON is not the same format as the open standard GeoJSON (note, this is not an OGC standard (Reed, 2011)), the OGC JSON response format. The JSON output from Esri endpoints represents the same data as a response from an OGC endpoint but is laid out differently and must be parsed into an in-memory geometry object before the two can be directly compared. We applaud offering both formats for the sake of broader compatibility. However, should older OGC servers be decommissioned we would recommend that Landgate offer WFS services from ArcGIS servers so that at least open standard GML would be available. Landgate could also, adventurously, offer GeoJSON from ArcGIS for Server with third party extensions.

Probably expand this section a little more.

7 FUTURE WORK

This work is by no means exhaustive. There remain several possibilities for expanding the application's reach and improving the depth of information generated from a campaign.

The foremost improvement to LandgateAPITest's functionality would be a more detailed investigation of the tests that failed their reference check, i.e. their response data did not match that stored in the web app database. This process could be semi-automated. Response data could be scanned for keywords such as "exception" in XML key/values to identify exception responses in place of the proper response data. Partial responses could be identified by longest common string comparison functions. Analysis of these categories of failed responses could provide more accurate insight into Landgate's server's suitability for mobile device traffic.

A closer collaboration with the Landgate team could permit the investigators to inspect the server logs for the web app's requests. The causes of failed requests could be discerned from a combination of the LandgateAPITest app data and the server's log data. Especially, we could relate server error conditions and logs to requests with a 500 response.

The OASIS Web Services Quality Factors (Kim et al., 2012) identify three types of latency in requests, ClientLatency, NetworkLatency and ServerLatency. Their sum being the total response time (that which LandgateAPITest records). Analysis of server logs could differentiate ServerLatency and NetworkLatency and compare latency in a variety of situations common to mobile devices.

Further development work could create a version of the LandgateAPITest mobile app suitable for Android OS devices. This would broaden the base of testers available and add another dimension to the result data. Investigation could show whether the different spatial server types offer better performance and reliability for iOS or Android devices.

This study only compared OGC services provisioned by Landgate's earlier server infrastructure. It would be instructive to see whether Esri provisioned OGC services compared favourably with other OGC servers.

Reference data can be considered in a more adaptable methodology than a straightforward equal/not equal test. The minor changes to GetCapabilities documents that caused their Reference Checks to fail wholesale could be averted through cleverer comparisons. Advanced string comparison techniques, such as longest common substring or edit distance, could be given a threshold similarity to assign success. For example, strings that are 90% the same could pass.

Success in collaborating with Western Australia's Landgate authority could be replicated with other Australian state cadastre authorities, such as NSW Land and Property Information. Given these organisations are not in competition, opportunities to learn from each other can lead to improved services for all Australian states.

8 CONCLUSIONS

This

Our study's contexts are in a state of nearly constant change. Web services have lost complexity due to the dominance of ReST APIs, but the number of services available has grown exponentially. Mobile devices have more processing power, larger batteries and faster connections to the internet. There are whole new categories of mobile devices, such as smartwatches, that change the mobile device landscape. Web service evaluation studies must be continually revisited just to keep pace with change.

Similarly, service providers must prepare for a changing landscape that may not even be partially realised yet. Landgate has evolved and changed direction since early in the decade to build the SLIP Future program. They must continue to adopt new technologies and processes so as to remain relevant to their customers.

In this work, we contribute to three aspects of the body of web service evaluation literature.

Firstly, we test services from an actual mobile device in real-world mobile usage situations. Tests are therefore as close to the real mobile experience as possible. This contrasts with the bulk of academic literature that performs tests on desktop computers emulating mobile devices.

Secondly, we examine more aspects of the interaction between client and server than merely average response time. Examining error responses and the conditions that lead to them give valuable insight into mobile-specific situations likely to result in errors.

Lastly, our examination of a single service provider, Landgate and WALIS's SLIP service, should produce practical and actionable recommendations to improve its suitability for mobile users. ——> Are these what were given in the recommendation section? If so it would be good to refer back to them.

REFERENCES

Agafonkin, V. (2015, October 26). Leaflet/Leaflet.heat. Retrieved May 2, 2016, from https://github.com/Leaflet/Leaflet.heat

Agafonkin, V. (2016, April 18). Leaflet. Retrieved from leafletjs.com/

ArcGIS for Server Features. (n.d.). ArcGIS for Server Features. Retrieved October 3, 2015, from http://www.esri.com/software/arcgis/arcgisserver/features

Cannata, M., Antonovic, M., & Molinari, M. E. (2014). Load testing of HELIDEM geo-portal: an OGC open standards interoperability example integrating WMS, WFS, WCS and WPS. *International Journal of Spatial Data Infrastructures Research, 6, 2011*, (9), 107–130. http://doi.org/10.2902/1725-0463.2014.09.ART5

Castillo, P. A., Bernier, J. L., Arenas, M. G., Merelo, J. J., & Garcia-Sanchez, P. (2011, May 25). SOAP vs REST: Comparing a master-slave GA implementation. *arXiv.org*.

Davis, C. A. J., Kimo, Y. J., & Duarte-Figueiredo, F. L. P. (2009). OGC Web Map Service implementation challenges for mobile computers. *2009 17th International Conference on Geoinformatics* (pp. 1–6). IEEE. http://doi.org/10.1109/GEOINFORMATICS.2009.5293410

Dedeoglu, K. (2015, November 11). kaandedeoglu/KDCircularProgress.

Endo, A. T., & Simao, A. S. (2010). A systematic review on formal testing approaches for web services. *Brazilian Workshop on Systematic and ....*

Fowler, S., Hameseder, K., & Peterson, A. (2012). An Empirical Evaluation of Web System Access for Smartphone Clients. *Journal of Networks*, *7*(11), 1–15. http://doi.org/10.4304/jnw.7.11.1700-1713

Gao, J., Bai, X., Tsai, W.-T., & Uehara, T. (2014). Mobile Application Testing: A Tutorial. *Computer*, *47*(2), 46–55. http://doi.org/10.1109/MC.2013.445

Google & Esri. (n.d.). Google & Esri. Retrieved September 27, 2015, from http://www.esri.com/landing-pages/products/google-lp

Google Maps Engine. (2014, October 14). Google Maps Engine. Retrieved September 30, 2015, from https://web.archive.org/web/20141014085033/http://www.google.com/work/mapsearth/products/mapsengine.html

Google Maps for Work - Mapping Software & Applications. (2014, November 22). Google Maps for Work - Mapping Software & Applications. Retrieved October 3, 2015, from http://web.archive.org/web/20141122022312/https://www.google.com/work/mapsearth/

Hamad, H., Saad, M., & Abed, R. (2010). Performance Evaluation of RESTful Web Services for Mobile Devices. *Int Arab J E-Technol.*

Huisman, O., & de By, R. (2009). Principles of Geographic Information Systems. ITC Educational Textbook Series.

Hussain, S., Wang, Z. S., & Toure, I. K. (2014). Performance Analysis of Web Services in Different Types of Internet Technologies. *Applied Mechanics and Materials*, *513-517*, 1431–1436. http://doi.org/10.4028/www.scientific.net/AMM.513-517.1431

Kanagasundaram, R., Majumdar, S., Zaman, M., Srivastava, P., & Goel, N. (2012). Exposing resources as Web services: A performance oriented approach (pp. 1–10). Presented at the Performance Evaluation of Computer and

Telecommunication Systems (SPECTS), 2012 International Symposium on, IEEE.

Kim, E., Lee, Y., Kim, Y., Park, H., Kim, J., Moon, B., et al. (2012). *Web Services Quality Factors Version 1.0* (pp. 1–29). Retrieved from http://docs.oasis-open.org/wsqm/WS-Quality-Factors/v1.0/cos01/WS-Quality-Factors-v1.0-cos01.html

la Beaujardiere, de, J. (2006). *OpenGIS® Web Map Server Implementation Specification* (1st ed.) (pp. 1–85).

Location Information Strategy Program Coordination Team. (2012, November 1). A Location Information Strategy for Western Australia. Retrieved April 16, 2015, from http://www.walis.wa.gov.au/projects/location-information-strategy-for-wa/locationstrategyassets/LIS%202.0%20November%202012.pdf

matplotlib/matplotlib. (2016, January 11). matplotlib/matplotlib.

Miao, L., Shi, X., & Cao, S. (2011). A scoring model for evaluating geospatial web services - A case study of OGC Web Map Service (pp. 1–4). Presented at the 2011 19th International Conference on Geoinformatics, IEEE. http://doi.org/10.1109/GeoInformatics.2011.5980738

Mills, A. (2015, December 11). ashleymills/Reachability.swift.

Mobile Performance Testing | Load Impact. (n.d.). Mobile Performance Testing | Load Impact. Retrieved October 11, 2015, from https://loadimpact.com/mobile-testing

Nguyen, T. T., Jørstad, I., & Thanh, D. V. (2008). Security and Performance of Mobile XML Web Services (pp. 261–265). Presented at the Fourth International Conference on Networking and Services (icns 2008), IEEE. http://doi.org/10.1109/ICNS.2008.41

NumPy — Numpy. (2016). NumPy — Numpy. *Numpy.org*.

Oriol, M., Marco, J., & Franch, X. (2014). Quality models for web services: A systematic mapping. *Information and Software Technology*, *56*(10), 1167–1182. http://doi.org/10.1016/j.infsof.2014.03.012

Our story - Landgate. (2015, August 28). Our story - Landgate. Retrieved September 24, 2015, from http://www0.landgate.wa.gov.au/about-us/our-story

Overview - Google Maps Engine API (Deprecated). (2015, February 18). Overview - Google Maps Engine API (Deprecated). Retrieved April 15, 2015, from https://developers.google.com/maps-engine/

Palacios, M., García-Fanjul, J., & Tuya, J. (2011). Testing in Service Oriented Architectures with dynamic binding: A mapping study. *Information and Software Technology*, *53*(3), 171–189. http://doi.org/10.1016/j.infsof.2010.11.014

Park, E., & Ohm, J. (2014). Factors influencing users' employment of mobile map services. *Telematics and Informatics*, *31*(2), 253–265. http://doi.org/10.1016/j.tele.2013.07.002

realm/realm-cocoa. (2016, March 26). realm/realm-cocoa.

Reed, C. (2011). OGC standards. In *Advances in Web-based GIS, Mapping Services and Applications* (pp. 327–348). CRC Press. http://doi.org/10.1201/b11080-26

SLIP Future Project. (2014). SLIP Future Project. Retrieved September 27, 2015, from https://www2.landgate.wa.gov.au/c/document_library/get_file?uuid=18853442-51bf-4a11-9ccc-76a61d891e51&groupId=10136

SLIP Stream. (2015a, July). SLIP Stream. Retrieved August 12, 2015, from http://slip.landgate.wa.gov.au/SiteAssets/Pages/SLIPStream/SLIPStream%20July%202015.pdf

SLIP Stream. (2015b, January 31). SLIP Stream. Retrieved April 16, 2015, from http://slip.landgate.wa.gov.au/SiteAssets/Pages/SLIPStream/SLIPStream%20January%202015.pdf

State Records Office of Western Australia. (2004, August 23). State Records Office of Western Australia. Retrieved September 24, 2015, from http://aeon.sro.wa.gov.au/Investigator/Details/Agency_Detail.asp?Entity=Global&Search=lands%20and%20surveys&Op=All&Page=1&Id=1576&SearchPage=Global

Statement of Corporate Intent 2015/16. (2015). *Statement of Corporate Intent 2015/16*. *www0.landgate.wa.gov.au*.

Telezhkin, D. (2016, January 9). DenHeadless/Transporter.

The ArcGIS REST API. (2015, August 31). The ArcGIS REST API. Retrieved October 1, 2015, from http://resources.arcgis.com/en/help/arcgis-rest-api/index.html

Tian, M., Voigt, T., Naumowicz, T., Ritter, H., & Schiller, J. (2004). Performance considerations for mobile web services. *Computer Communications*, *27*(11), 1097–1105. http://doi.org/10.1016/j.comcom.2004.01.015

Vretanos, P. P. A. (2005). *Web Feature Service Implementation Specification* (1st ed.) (pp. 1–131).

Web Services Glossary. (2004, February 11). Web Services Glossary. Retrieved October 4, 2015, from http://www.w3.org/TR/2004/NOTE-ws-gloss-20040211/#webservice

Welcome to webapp2! — webapp2 v2.5.1 documentation. (2011). Welcome to webapp2! — webapp2 v2.5.1 documentation. *Webapp-Improved.Appspot.com*.

Wu, H., Li, Z., Zhang, H., Yang, C., & Shen, S. (2011). Monitoring and evaluating the quality of Web Map Service resources for optimizing map composition over the internet to support decision making. *Computers & Geosciences*, *37*(4), 485–494. http://doi.org/10.1016/j.cageo.2010.05.026

Xcode - What's New - Apple Developer. (n.d.). Xcode - What's New - Apple Developer. Retrieved April 20, 2016, from https://developer.apple.com/xcode/

Yan, M., Sun, H., Wang, X., & Liu, X. (2012). WS-TaaS: A Testing as a Service Platform for Web Service Load Testing. Presented at the ICPADS '12: Proceedings of the 2012 IEEE 18th International Conference on Parallel and Distributed Systems, IEEE Computer Society.

Yang, P., Cao, Y., & Evans, J. (2013). Web Map Server Performance and Client Design Principles. *GIScience & Remote Sensing*, *44*(4), 320–333. http://doi.org/10.2747/1548-1603.44.4.320

APPENDIX A WEB SERVICE GET REQUESTS