Demand Forecasting for Network Bandwidth
A Mosaic Data Science Case Study

Background

One of the world's leading and top-rated management consulting firms was preparing to move their video conferencing and audio conferencing capabilities from an in-office hosted solution to Cisco WebEx. High-quality, seamless video and audio communication is critical to maintaining this firm's customer-facing reputation and to effective use of high-value company resources.

The firm's internal Information Technology (IT) team was tasked with facilitating a smooth transition, requiring that adequate network connectivity be established and available from each office to support the WebEx sessions which the firm needs to conduct on top of other network traffic. The consulting firm has 85 offices in 48 countries with over 6,200 consultants and around 12,000 total staff. The firm believed that through analysis of their historical data along with predictive modeling they could build forecasts for how much bandwidth was needed at each office.

Mosaic was contracted as a strategic data science consultant to provide quantitative and predictive analyses of these systems to give the client confidence that after the transition the bandwidth would be sufficient to support the firm's daily operational needs. In addition, the management consulting firm also desired the ability to update results quickly and easily in order to monitor changes in usage, requirements, or other characteristics affecting the results.

Mosaic was able to draw upon its wealth of analytics consulting experience to provide an easily updateable web application that provides quick and informative analysis of the audio/video conferencing system allowing the customer to make data-driven decisions.

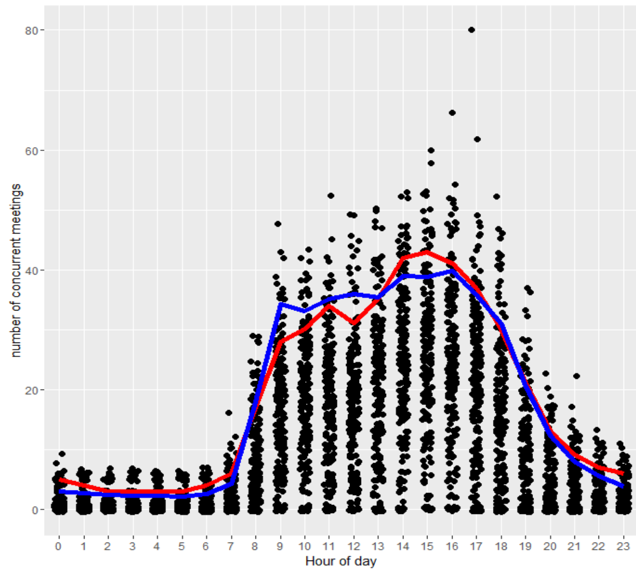
Analysis

Mosaic modeled the bandwidth requirements of the WebEx service, which is to be carried over dedicated network links. The modeling tasks included gaining access to, understanding, and organizing the data, predicting future bandwidth requirements based on current requirements, evaluating the accuracy of the predictive models, and documenting the tools created and the processes followed to create those tools. The main data sources for the model included employee count by hour by office, and detailed online meeting information.

Data preparation was a key component to developing a solution that effectively addressed the customer's needs. The team calculated the number of concurrent meetings by office and hour. They translated online meeting start times and end times (for each office) and output the number of concurrent sessions per hour.

The data used to fit the model covered approximately 10 months of the customer's daily business operations. The forecasting model for the number of meetings under future operating conditions would be based solely on historical data. Deriving the bandwidth requirements from this forecast would depend on the inputs the user selects.

One challenge the client faced was that the method they chose had to allow the Mosaic team to model a high estimate of predictions by office and hour. A high estimate would be more relevant than an average because it would give the client a better idea of exactly when and how often they are nearing bandwidth capacity. In other words, predicting the average number of concurrent meetings with linear regression would lead to an underestimation of bandwidth requirements leading to poor-quality online



meetings and dropped connections. Likewise, modeling the maximum would lead to an overestimation of bandwidth requirements and too much money spent. Mosaic chose the 90th percentile of the data for the high estimate, as this best met the requirements stated above.

To overcome this challenge, the Mosaic team investigated a number of solutions including modeling the data with quantile regression and linear regression but taking the high estimate of the prediction interval. In the end, an ostensibly simple path was chosen: to remove up to the 50th percentile (depending on the amount of data available for each office) of the distribution of the number of concurrent meetings. This data was then modeled by a linear mixed effects (LME) model. The LME model assumes a linear relationship between the number of people in the office and the number of concurrent meetings and allows this linear relationship to vary by office and hour of the day. To evaluate the performance of this model the team performed the following steps:

1. For each office, all the available data was used to calculate the 90th percentile of the hourly number of concurrent meetings. This is the reference curve with which we compare the model output to evaluate performance.
2. For each office, all the available data was used to calculate the 90th percentile of the hourly number of employees for each hour of the day.
3. The model was evaluated using as input the employee counts obtained in step 2. The output of the model is the expected number of concurrent meetings
4. The curves obtained in steps 1 and 3 were compared.

The above procedure was repeated for all offices. The following figure shows the comparison of the predicted (in blue) versus actual (in red) curve for a specific office.

Figure 1: Comparison of Historical data (red line) vs Model (blue line)

The team obtained an error estimate for each office by averaging the 9am to 5pm error and normalizing by the total number of meetings in that time period. This was done for each office and included web app output.

Visualization

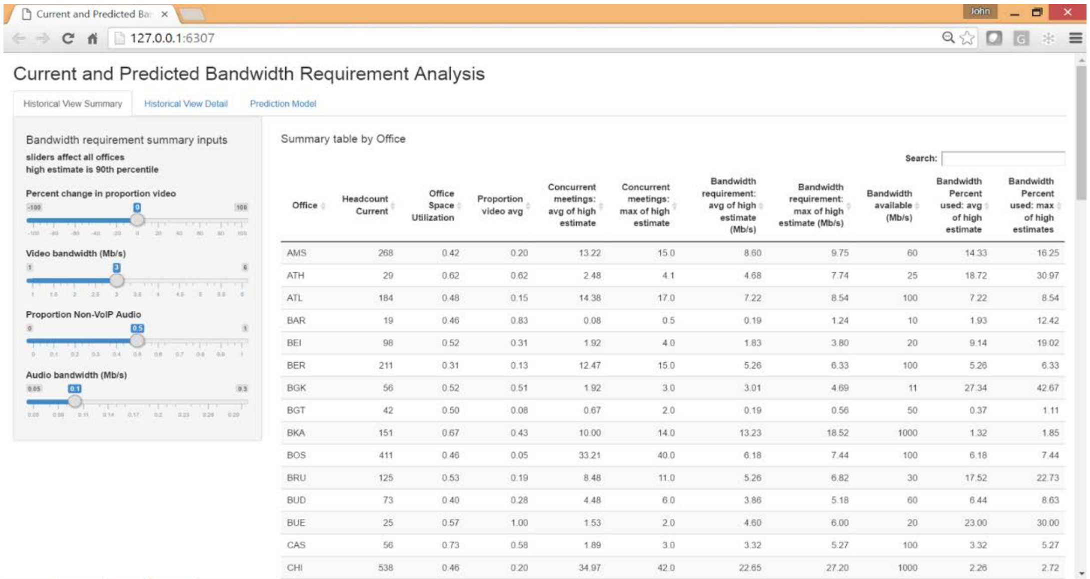
In addition to creating the predictive model, the Mosaic team recognized that an interactive view of the historical data and predictive model would be very useful and informative to the customer for making data-driven decisions. To that end, the team used the R Shiny package to develop an interactive web application that allows viewers to see projected bandwidth needs at a chosen office under a given set of future operating conditions. The Shiny app provides location-specific default operating conditions derived from the historical data when a user selects a location to view but also allows users to interactively adjust the parameters that define the operating conditions in order to see how differing assumptions impact predicted bandwidth usage. Example parameters include:

- Office Space Utilization - expected number of employees in the office on a given day
- Proportion Video - the proportion of video vs audio-only attendees of meetings
- Video Bandwidth - bandwidth required for video data
- Audio Bandwidth - bandwidth required for audio data
- Proportion Non-VOIP Audio – for example, calling in to a meeting with a cell phone

The interactivity enabled by the Shiny app allows stakeholders to adjust for expected vs actual changes in operating conditions (such as number of employees in an office) over time. The client plans to add data to the analysis on an ongoing basis so that they can continuously predict bandwidth requirements as the needs change.

In addition, many of the inputs are variable by office, day, and hour (e.g. the proportion video is not constant for each office, day, or hour) so having the flexibility to change the input can make the derived prediction of the bandwidth requirements more accurately reflect reality.

The Shiny app is set up so that the first tab displays an overall summary of the analysis. This allows users to quickly identify potential problem offices that are nearing their bandwidth capacities. Two of the columns the app displays are the Bandwidth Percent used: average of high estimate and max of high estimate. These two columns allow the user to identify if and how consistently the office is nearing bandwidth capacity. A screenshot is shown below. The sliders in the grey box on the left affect the derived bandwidth requirements. Note the last two columns of the table.



Office	Headcount Current	Office Space Utilization	Proportion video avg	Concurrent meetings: avg of high estimate	Concurrent meetings: max of high estimate	Bandwidth requirement: avg of high estimate (Mb/s)	Bandwidth requirement: max of high estimate (Mb/s)	Bandwidth available (Mb/s)	Bandwidth Percent used: avg of high estimate	Bandwidth Percent used: max of high estimates
AMS	268	0.42	0.20	13.22	15.0	8.60	9.75	60	14.33	16.25
ATH	29	0.62	0.62	2.48	4.1	4.68	7.74	25	18.72	30.97
ATL	184	0.48	0.15	14.38	17.0	7.22	8.54	100	7.22	8.54
BAR	19	0.46	0.83	0.08	0.5	0.19	1.24	10	1.93	12.42
BEI	98	0.52	0.31	1.92	4.0	1.83	3.80	20	9.14	19.02
BER	211	0.31	0.13	12.47	15.0	5.26	6.33	100	5.26	6.33
BGK	56	0.52	0.51	1.92	3.0	3.01	4.69	11	27.34	42.67
BGT	42	0.50	0.08	0.67	2.0	0.19	0.56	50	0.37	1.11
BKA	151	0.67	0.43	10.00	14.0	13.23	18.52	1000	1.32	1.85
BOS	411	0.46	0.05	33.21	40.0	6.18	7.44	100	6.18	7.44
BRU	125	0.53	0.19	8.48	11.0	5.26	6.82	30	17.52	22.73
BUD	73	0.40	0.28	4.48	6.0	3.86	5.18	60	6.44	8.63
BUE	25	0.57	1.00	1.53	2.0	4.60	6.00	20	23.00	30.00
CAS	56	0.73	0.58	1.89	3.0	3.32	5.27	100	3.32	5.27
CHI	538	0.46	0.20	34.97	42.0	22.65	27.20	1000	2.26	2.72

Figure 2: Historical View Summary of Web App

The next screenshot shows the 'Historical View Detail' tab. The user can delve more deeply into the situation and view the number of concurrent meetings, employees at the office, and derived bandwidth requirements, by office and hour. As above, the inputs on the left will affect the plot output.

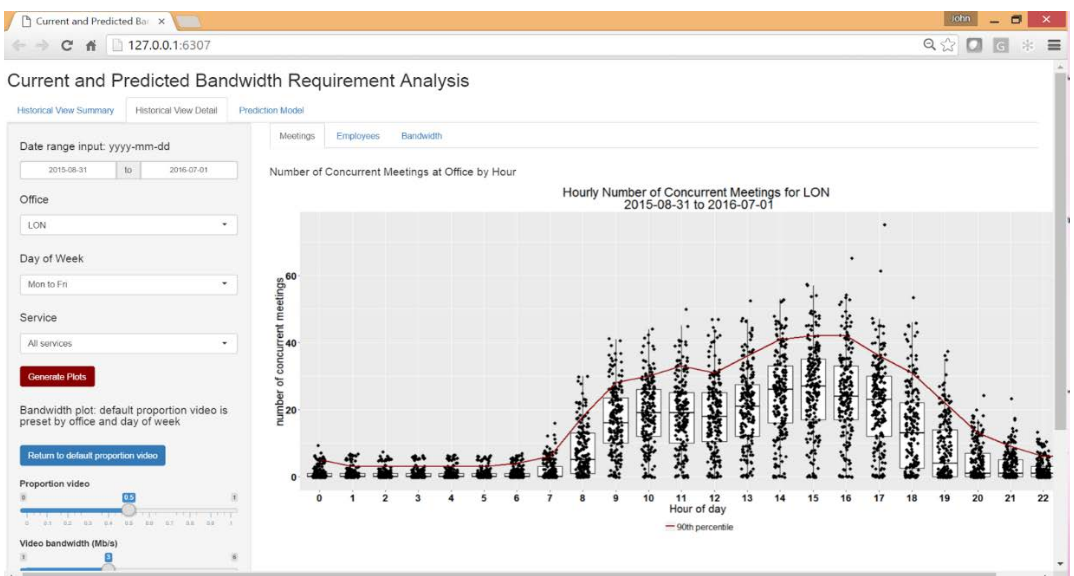
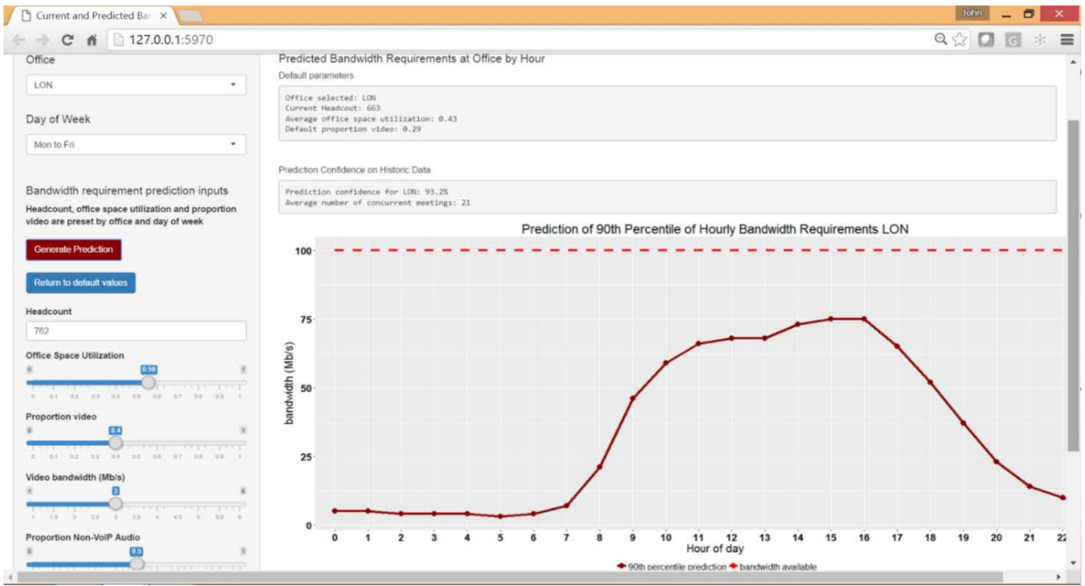


Figure 3: Historical View Detail, hourly number of concurrent meetings with 90^{th} percentile (red line)

The Prediction Model tab allows the user to investigate bandwidth requirements using inputs that fall outside of the historical data. For example, the user can input a higher number of employees at an office (headcount) simulating an office expansion and see whether or not there is enough bandwidth capacity.



Due to Mosaic's detailed analysis and interactive web app providing the ability to perform what-if analyses, the customer is now able to better understand how future changes will impact bandwidth

Figure 4: Predicted Bandwidth Requirements: high estimate (90th pct)

needs at existing and new office locations. This will allow for better and more efficient planning and use of resources, fewer dropped calls and consistent high quality audio and video ensuring the firm's exceptional customer-facing reputation. Perhaps of even greater importance, is that Mosaic's analysis has changed how the customer thinks about these decisions. After seeing the results for the first time, one IT leader exclaimed, "We've never been able to make decisions in this way before!" How can analyses like this one change the way you do business?

Want to learn more? Please contact info@mosaicdatascience.com