The challenge at hand was to develop a "simple" tool for estimating the middle mile cross section required to support acceptable[1] internet use by our target constituents. The enclosed tables are the simplest that I could assemble, using numerous typical and average figures, and erring to the cautious side. While actual design considerations would be iterative once such a network is implemented and its real usage profiles are established, such is not possible at this time hence the caution in estimates. Time of day, type of application, last mile capability, and other statistical usage parameters are not explicitly considered, especially the impact of small numbers of proximate users. The resultant tables reflect the most common sizing estimates I uncovered, which estimates are based on real world experience, and have been checked against our company's experience here in Alaska (though variations among states are not significant at this level of precision.)

The estimates on each table are calculated using an over-subscription rate that ranges from 10 to 12.Over-subscription results from the net of all effects of the usage profiles of each user, and in the case of these tables allows for 10 to 12 times as many users to be theoretically using the capacity as their download and upload data rates would indicate. The larger the number of users, the larger the over-subscription rate can be; these values do not fully discount this effect, but do maintain a conservative approach. On the other hand, as the number of users approaches one, the real ability to over-subscribe is reduced. The 10-12 rate is a useful estimate for the ranges in the study.

	Middle Mile Cross Section Required	
No. of Users	10 X Over-subscription (Mbps)	12 X Over-subscription (Mbps)
10	100	83
20	200	167
50	500	417
100	**1,000**	833
200	2,000	1,667
500	5,000	4,167
1,000	**10,000**	8,333
2,000	20,000	16,667
5,000	50,000	41,667
10,000	100,000	83,333

Table 1: Cross section capacity required for 100 Mbps service for each user[2]

Table 1 indicates the total bandwidth required for various "downstream" user counts, for the targeted 100 Mbps service. For 100 users, the required capacity is 1,000 Mbps, or in Ethernet terms, a "GigE." Note that at the 1,000 user level an entire wavelength on a fiber pair is needed, a 10GigE (though newer technologies

[1] Though *acceptable* in this context is subject to a wide variety of interpretations, the Task Force has used in its mission a simple reference – 100 Mbps for every Alaskan. The definition of "acceptable" is subject to later revision.

[2] "User" in this context refers to households, inasmuch as the connections to the broadband are counted by household. Based on 2011 data, there are an average of 2.68 persons per Alaskan household.

can push more data than on a single wavelength.) For 10,000 users the 10 wavelengths needed can still consume less than the full capacity of a single fiber pair (30 to 60 wavelengths or more are possible using dense wave division multiplexing - DWDM.)

	Middle Mile Cross Section Required	
No. of Users	10 X Over-subscription (Mbps)	12 X Over-subscription (Mbps)
10	4	3
20	8	7
50	20	17
100	40	33
200	80	67
500	200	167
1,000	400	333
2,000	800	667
5,000	2,000	1,667
10,000	4,000	3,333

Table 2: Cross section capacity required for 4 Mbps service for each user

Table 2 shows the corresponding cross section required to provide 4 Mbps service (rather than 100 Mbps) as a comparative reference. This level was chosen as it represents the "slowest" speed popularly put forth as a ubiquitous requirement. Note that a GigE can support between 2,000 and 5,000 users, and the 10,000 user service can be satisfied by a single fiber wavelength, with plenty of room to spare!

Since digital microwave radios are popular alternatives for fiber optic cables in Alaska, additional consideration has been given to quantify their ability to serve as adjuncts to the fiber optic based network. Such systems are used in applications that require less bandwidth than fiber optic systems, and in applications such as Alaska's Southeastern region where mountaintop radio "hops" offer access to many more locations than fiber optic cables, and under different, generally more cost-effective financial bases. The systems used in the table below are typical of those used in Alaska, built with modern radio and protection equipment. Each radio link contains seven separate radios, each carrying 160 Mbps. The systems are designed with one of the radios as a spare for the other six, known as a 6 + 1 system. This spare channel, known as the protection channel is able to instantly take over the signal of any one of the others, based on equipment failure or radio path failure. In so doing, these systems offer reliability comparable to a fiber optic system, but with significantly less carrying capacity, as the table shows.

	Bandwidth per user per M/W system	
No. of Users	10 X Over-subscription (Mbps)	12 X Over-subscription (Mbps)
10	960	1,152
20	480	576
50	192	230
100	96	115
200	48	58
500	19	23
1,000	10	12
2,000	5	6
5,000	2	2
10,000	1	1

Table 3: Available download/upload speed per user on a microwave radio system

Notice that the entire 6 +1 radio system is consumed with approximately 100 users – not very cost efficient! Allowing for the 4 Mbps allocation per user, however, a microwave system could support more than 2,000 users! Thus such systems could play only a very limited role in a system with 100 Mbps service.

In summary, please recall that these tables are conservative by design, but that they point out one straightforward truth – to provide 100 Mbps service will almost certainly require fiber optic service to every location in the state with more than 100 users!

Network "design" and determination of average cost per mile for fiber optic systems and microwave radio systems are the next steps we will undertake.