Q1: Why is the Last Mile an important and complex issue in Networking and Communications?

A1:

In Networking and Communications, Last Mile refers to the issue of how to deliver the network services to the end-users physically. Instead of large business users and professional communication companies, end-users involved in the Last Mile issue are just ordinary users. Therefore, communications like SMF which is commonly used in backbone network would not be used when it comes to the connection between service providers and end-users.

Last Mile is an important and complex issue in Networking and Communications. As we've mentioned above, Last Mile issue is about delivering the network to individuals. The cost can be determined by lots of factors which includes weather condition, technological level and other issues, while different individuals may live in very different environments. Therefore, service providers need to apply communications according to local conditions.

A general approach to solve the Last Mile issue is to mix copper with fiber. We'd discuss this in the later questions.

Q2: What are the main, typical, options for delivering Last Mile networks in Australia?

A2:

Various solutions are provided to solve the Last Mile issue in Australia, which could be classified into ADSL, VDSL, FTTx and wireless approaches.

ADSL, which is short for Asymmetric Digital Subscriber Line, is a kind of DSL technique. Asymmetric means that bandwidth and bit rate are asymmetric in ADSL. In other words, downstream is greater than upstream. Depending on the distance, user is supposed to get speeds of up to 12.0 Mbit/s.

An upgrade for ADSL is ADSL2+, which was approved in 2003. With ADSL2+, user may expect a downstream rate up to 24.0 Mbit/s and an upstream rate up to 3.3 Mbit/s, depending on the distance. Currently almost all network providers in Australia has ADSL plan for their users, Telstra, for example.

VDSL stands for Very High Speed Digital Subscriber Line, which is another option basing on copper. Literally, VDSL has a very high speed with more carrier frequencies. One may expect a downstream rate up to 55 Mbit/s from VDSL, while VDSL2+, an upgrade of VDSL, may provide end-user with up to 300Mbit/s downstream rate.

FTTx is a common concept known as "fiber to the x", where x can be Node (FTTN), Curb (FTTC), Building (FTTB), home (FTTH) and so on. It is reported that 93% NBN customers are using FTTx services.

FTTN stands for Fiber to the Node. Usually fiber would terminate miles away from the end-users, then copper is used for the final connection. FTTN is also considered as an intermediate step of FTTH.

FTTK, short for Fiber to the Kerb, is similar to FTTN. But in FTTN, fiber would terminate miles away from the end-users, while FTTK would terminate several hundred meters away from users. FTTK may provide user up to 100Mbit/s

FTTH, short for Fiber to the Home. Fiber would directly reach the boundary of the living space and may provide user with up to 10 Gbit/s.

Wireless approaches are also being used in Australia. Besides 3G and 4G network, it is reported that 3% Australian are using satellite communications.

Q3: What are the inherent (physical) limitations on data-rates across typical Last Mile networks? [15%]

If ADSL are used, one may expect a downstream rate up to 12.0 Mbit/s, and a downstream rate up to 24.0 Mbit/s with ADSL2+. Currently most Australian companies which provide ADSL services are using ADSL2+, so user may expect up to 24.0Mbit/s downstream rate.

Distance (from DSLAM)	Download Speed (Megabytes per second)	Download Speed (Megabits per second)	Download Time Example (9.3MB MP3 file)
0.3 km (approx 0.19 miles)	3.0 MB/sec	24.0 Mbit/s	~3.0 seconds
0.6 km (approx 0.37 miles)	3.0 MB/sec	24.0 Mbit/s	~3.0 seconds
0.9 km (approx 0.56 miles)	2.88 MB/sec	23.0 Mbit/s	~3.2 seconds
1.2 km (approx 0.75 miles)	2.75 MB/sec	22.0 Mbit/s	~3.4 seconds
1.5 km (approx 0.93 miles)	2.63 MB/sec	21.0 Mbit/s	~3.5 seconds
1.8 km (approx 1.12 miles)	2.38 MB/sec	19.0 Mbit/s	~3.9 seconds
2.1 km (approx 1.3 miles)	2.0 MB/sec	16.0 Mbit/s	4.7 seconds
3.0 km (approx 1.86 miles)	1.0 MB/sec	8.0 Mbit/s	9.3 seconds
4.5 km (approx 2.80 miles)	0.38 MB/sec (384 KB/sec)	3.0 Mbit/s	~24.5 seconds
5.2 km (approx 3.23 miles)	0.19 MB/sec (192 KB/sec)	1.5 Mbit/s	~49 seconds

Figure 1. ADSL2+ Download Speed[1]

However, ADSL communication can be largely affected by the distance. The longer distance to the end-user, the worse SRN will be, and the down speed would decrease linearly.

Version	Standard name	Common name	Downstream rate	Upstream rate	Approved on
VDSL	ITU G.993.1	VDSL	55 Mbit/s	3 Mbit/s	2001-11-29
VDSL2	ITU G.993.2	VDSL2	200 Mbit/s	100 Mbit/s	2006-02-17
VDSL2-Vplus	ITU G.993.2 Amendment 1 (11/15)	VDSL2 Annex Q VPlus/35b	300 Mbit/s	100 Mbit/s	2015-11-06

Figure 2. VDSL Download Speed[2]

VDSL can provide its end-user with up to 55 Mbit/s downstream rate, while VDSL2+ may provide up to 300 Mbit/s. However, VDSL's performance can be largely affected by the distance between network provider and end-user. Generally, VDSL is used when the distance is less than 1 km. 1.2 km is regarded as a maximum range of VDSL, and if the distance is over1.6 km, VDSL and ADSL would have a similar performance when it comes to the down speed.

FTTx is fast and stable, however, FTTx is heavily depend on fiber, which is more expensive than copper.

Wireless approach is quite common and widely used, but it can be affected by lots of factors, weather condition, for instance.

Q4:

Suppose all farms are distributed as Figure 3 shows. 900 farms are placed in a 30 x 30km square region, each farm takes an 1x1 km ground.

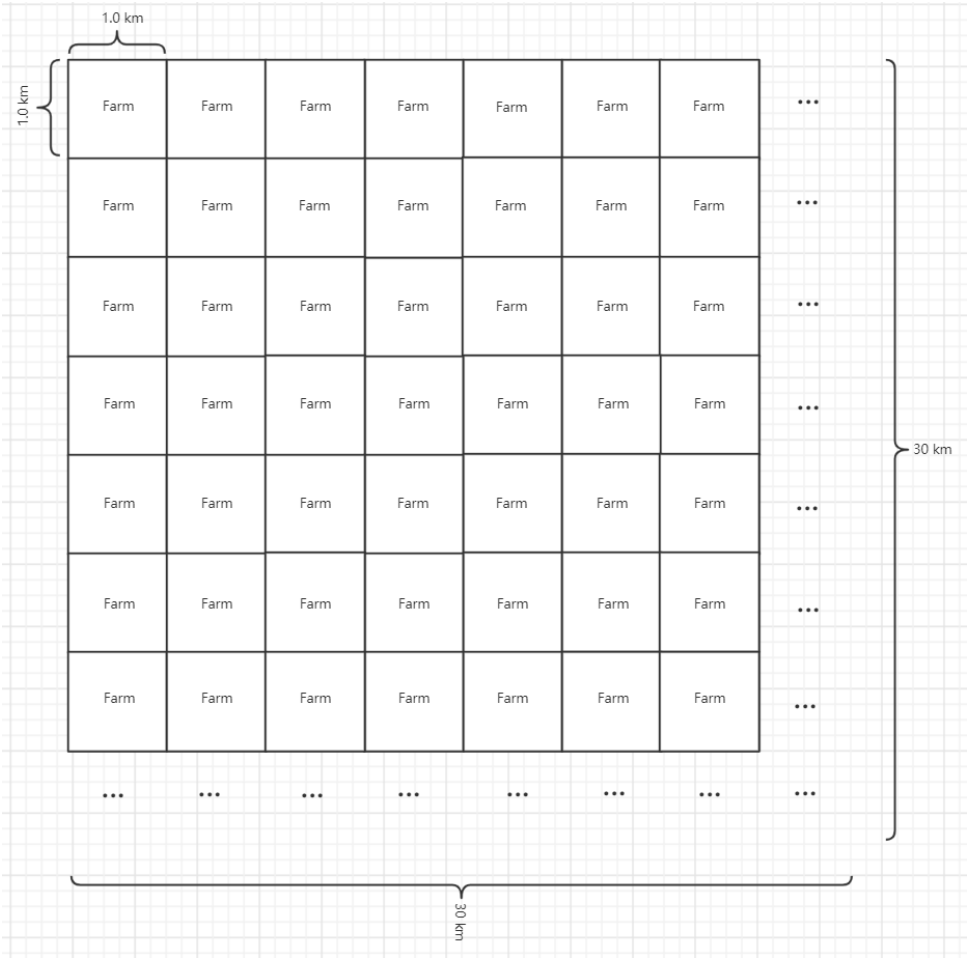

Figure 3. Farm Distribution

According to the requirement, 16 exchanges are evenly distributed. Therefore exchanges should be distributed as Figure 4 shows.

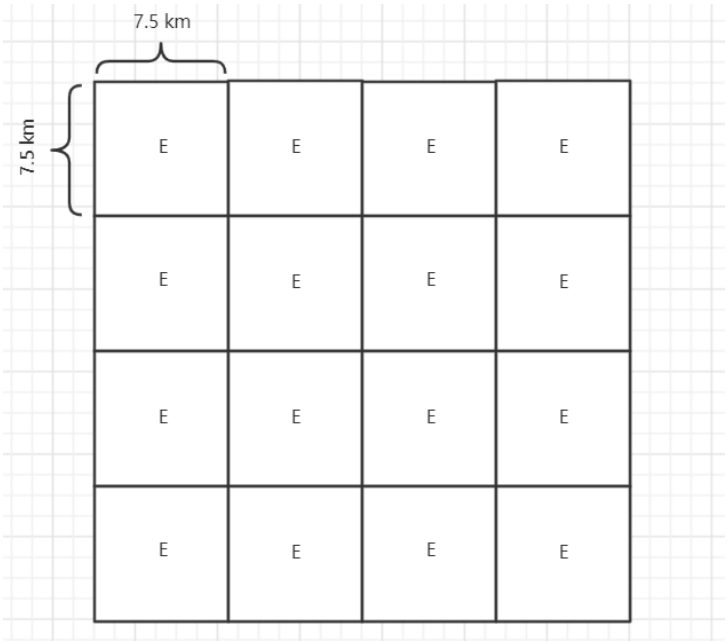

Figure 4. Exchange Distribution

Suppose each cell in figure 4 stands for a 7.5 x 7.5 km ground as it shown in figure 5,

where “E” stands for an exchange. (Here I just use 7 x 7, but should be 7.5 x 7.5)

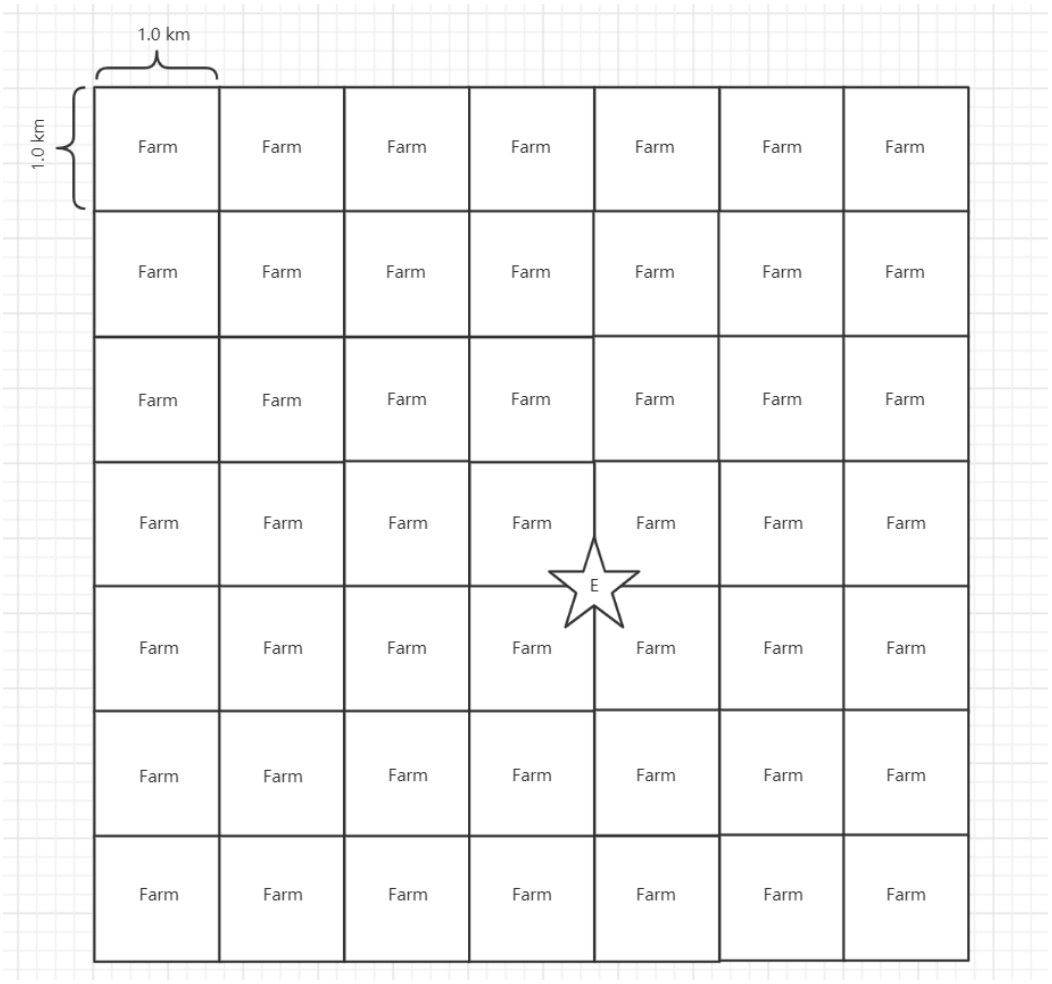

Figure 5. Farm – Exchange distribution for each unit

1. ADSL

Version	Standard name	Common name	Downstream rate	Upstream rate	Approved in
ADSL	ANSI T1.413-1998 Issue 2	ADSL	8.0 Mbit/s	1.0 Mbit/s	1998
	ITU G.992.2	ADSL Lite (G.lite)	1.5 Mbit/s	0.5 Mbit/s	1999-07
	ITU G.992.1	ADSL (G.dmt)	8.0 Mbit/s	1.3 Mbit/s	1999-07
	ITU G.992.1 Annex A	ADSL over POTS	12.0 Mbit/s	1.3 Mbit/s	2001
	ITU G.992.1 Annex B	ADSL over ISDN	12.0 Mbit/s	1.8 Mbit/s	2005
ADSL2	ITU G.992.3 Annex L	RE-ADSL2	5.0 Mbit/s	0.8 Mbit/s	2002-07
	ITU G.992.3	ADSL2	12.0 Mbit/s	1.3 Mbit/s	2002-07
	ITU G.992.3 Annex J	ADSL2	12.0 Mbit/s	3.5 Mbit/s	2002-07
	ITU G.992.4	Splitterless ADSL2	1.5 Mbit/s	0.5 Mbit/s	2002-07
ADSL2+	ITU G.992.5	ADSL2+	24.0 Mbit/s	1.4 Mbit/s	2003-05
	ITU G.992.5 Annex M	ADSL2+M	24.0 Mbit/s	3.3 Mbit/s	2008

Figure 6. ADSL speed[3]

As the requirement states, every farm is supposed to get at least 50Mb/s down. If ADSL is used, one may expect a downstream rate up to 12 Mbit/s, which cannot meet the requirement. Even if ADSL2+ is implemented, a 24.0 Mbit/s down speed cannot satisfy the requirement. Therefore, ADSL approach is unavailable in this situation.

2. VDSL

As the it shown in figure 2, it seems that VDSL could satisfied our requirement with a max down speed of 300 Mbit/s. However, we've discussed in Q3 that VDSL's performance deteriorates rapidly after a certain distance.

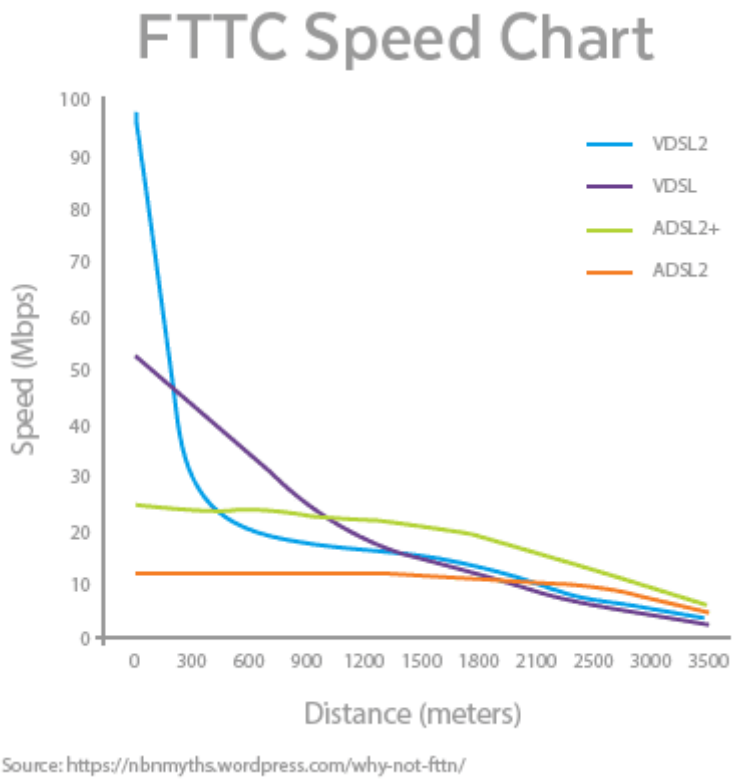

Figure 7. FTTC Speed Chart[4]

As it shown in Figure 7, VDSL's down speed drops rapidly with the growth of distance. In this situation, any farm which is 4 km away may not expect an ideal speed. In other word, the down speed can be less than 3Mbit/s, so we cannot use VDSL.

3. Fiber

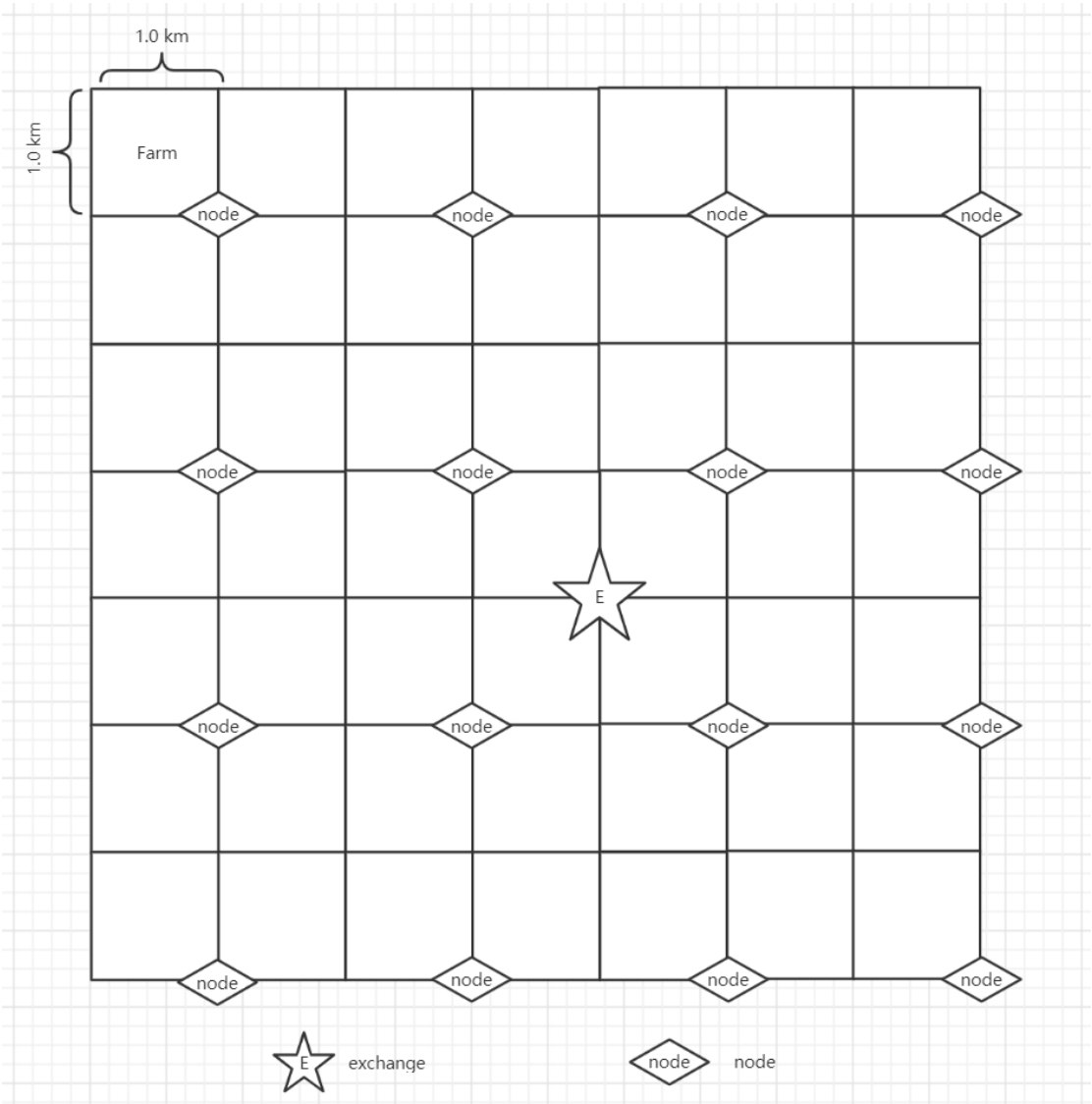

Figure 8. Fiber design

Theoretically speaking, all FTTx approaches satisfy our requirement. Equipped with fiber, FTTx is fast enough, and barely affected by distance comparing with DSL technique.

By the consideration of economic interests, we'd like to choose FTTN/C rather than FTTP or FTTH in this situation. Comparing with FTTP/FTTH, FTTN/C use copper wires to complete the final connection, which is cheaper than using fiber.

The design is shown in figure 8 for each exchange. There would be 16 exchanges, 15 * 15 = 225 nodes, while fiber would be used to connect exchanges and nodes, and copper will be used for final connection.

The total cost can be calculated in this way:

a. Fiber cost:

There are 225 nodes, so total distance is 450km. $10/meter for the fiber cable, and $500 for terminating each end. Hence the total cost is:

$$450000 \times 10 + 225 \times 500 = 4500 = 4612500$$

b. Copper cost:

There are 900 farms, each farm is 50 meters away from node, $3/meter for the copper cable, and $150 for terminating each end. Therefor copper cost is:

(3 x 50 + 150) x 900 = 270000

Hence, the total cost should be $4,882,500

4. Wireless approach

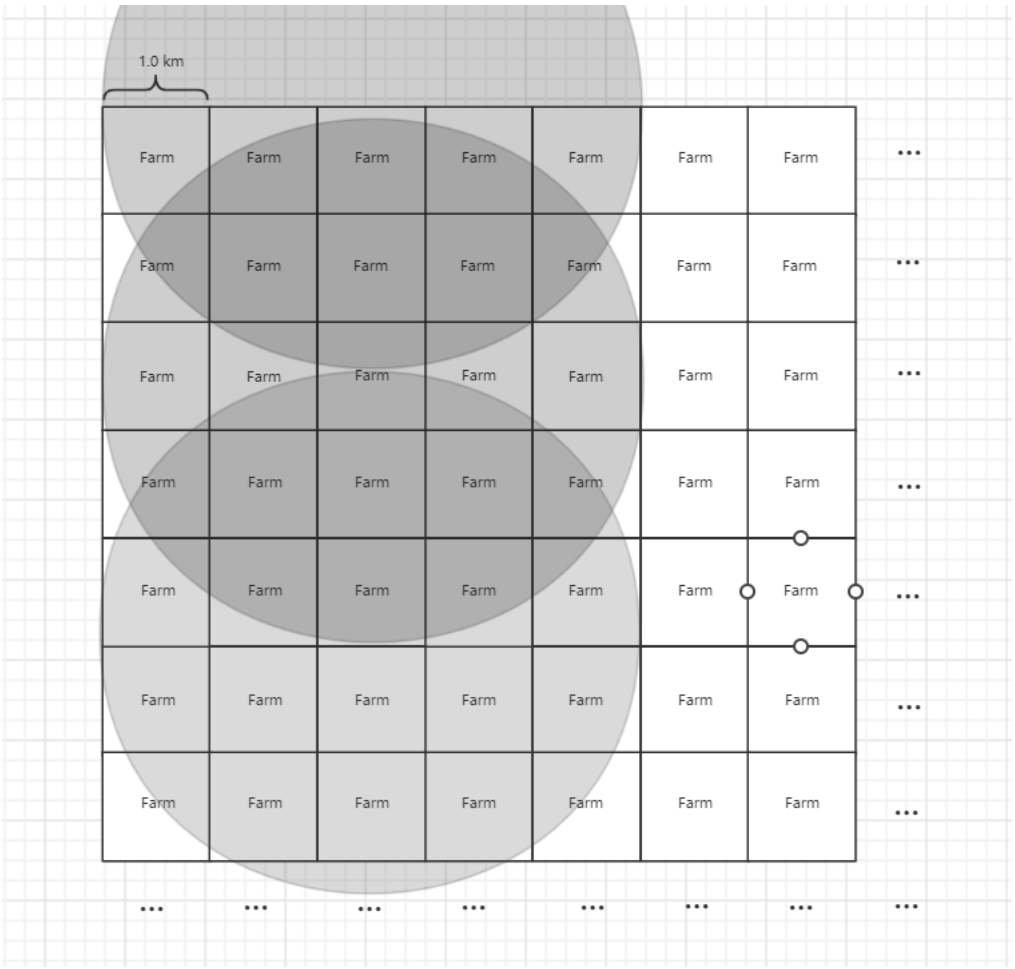

Figure 9. omnidirectional transmitters solution

Wireless approach is also available in this situation. However, By the consideration of stability, we'd not recommend wireless approach as the best plan. Wireless network may be affected by a great number of factors, weather condition, for example.

Another issue that need to be considered is maintenance. If both Point-to-point links and Omnidirectional transmitters are used, maintainer can hardly tell where the problem is if a user lost connection to the network.

Suppose omnidirectional transmitters are used, there should be 121 Wireless transmitters to cover all 900 farms, and each farm needs an extra $500.

Hence, the total cost should be:

121 x 20000 + 900 x 500 = 2870000

As a conclusion, we'd recommend FTTN/C as the best plan. Both ADSL and VDSL cannot meet the requirement, while wireless approach still has lots of improvement.

Resources:

[1] https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line
[2] https://en.wikipedia.org/wiki/VDSL
[3] https://en.wikipedia.org/wiki/Asymmetric_digital_subscriber_line
[4] https://www.versatek.com/blog/most-frequently-asked-vdsl2-questions/