

# Browan Sensor Performance Analysis on the Helium Network

## Contents

Executive Summary.....	1
Introduction & Problem Statement.....	4
Systems Overview.....	6
Systems Performance Summary.....	7
Observations.....	7
Packet Completion Rate – System Level.....	7
Packet Completion Rate – Per Sensor.....	8
Rogers System Sensors.....	8
Sunrise System Sensors.....	8
Longview System Sensors.....	8
Spreading Factor Analysis.....	9
Systems Performance Detailed Analysis.....	13
Longview System Performance over Time.....	13
Rogers System Performance over Time.....	15
Sunrise System Performance over Time.....	16
Appendix A - Performance Measurement Methodology.....	19
Appendix B – System and Individual Sensor Performance Graphs for the Longview System.....	21
Appendix C – System and Individual Sensor Performance Graphs for the Sunrise System.....	30
Appendix D – System and Individual Sensor Performance Graphs for the Rogers System.....	34
Appendix E – Data Files.....	39

## Executive Summary

Hitechdb, a Helium partner, has 3 systems on the Helium network, consisting of various Browan sensors. All 3 systems exhibited similar behavior, namely that performance, as defined by Packet Completion Percentage, declined from near 100% to 20-30% within 18 – 23 days of system deployment. Performance has remained at the low level ever since.

After a detailed analysis of the log data, it appears that the root cause of the decline in performance is tied to change in spreading factor. Specifically,

- When the sensor is activated, the SF starts at 7 then over time increments to 10
- Shortly after achieving a spreading factor of 10, the packet completion rate for the sensor drops dramatically

The charts below for sensor TBHH100\_6 demonstrate this phenomenon.

This rest of this report contains the data analysis and is organized into the following sections:

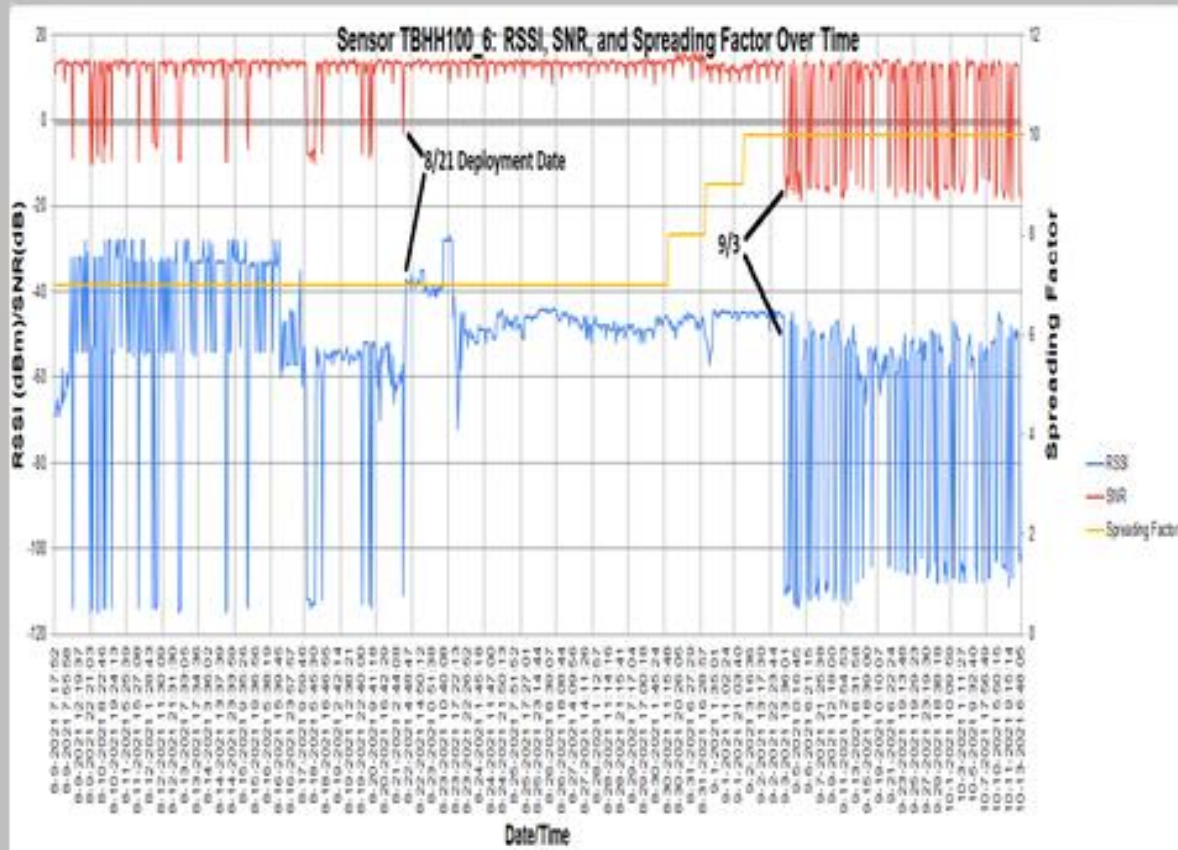
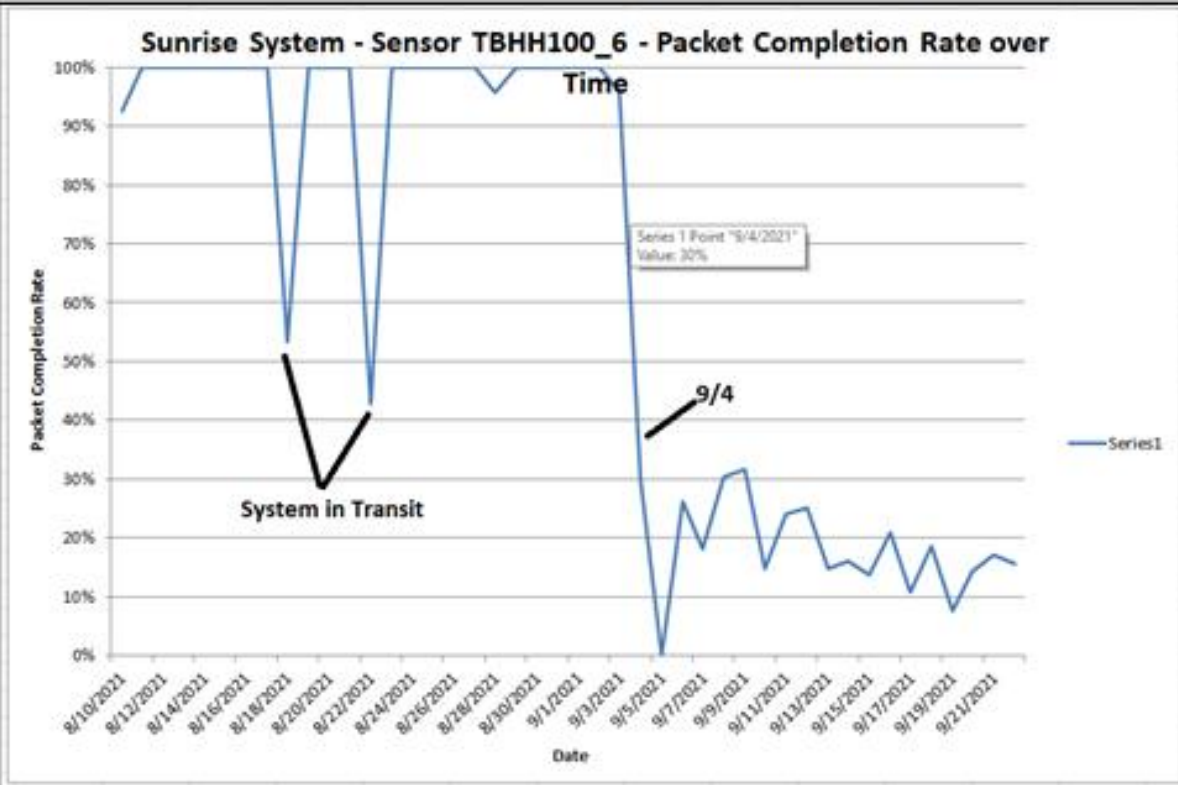
- Systems Overview: describes the makeup of the 3 systems, including location, sensor, and gateway details

- Systems Performance Summary: describes the overall performance of each of the 3 systems
- Observations: provides a high level summary of observations after reviewing the system and sensor graphs
- Systems Performance Detailed Analysis: detailed performance analysis of each sensor in each system
- Appendix A: performance Measurement Methodology: explains how performance is measured
- Appendix B: performance graphs for the Longview System
- Appendix C: performance graphs for the Sunrise System
- Appendix D: performance graphs for the Rogers System
- Appendix E: information on the data files used in the analysis

This report and the supporting data files can be obtained from the following location:

<https://github.com/mikedsp/helium/tree/master/Browan%20Sensor%20Performance%20Analysis%20on%20the%20Helium%20Network>

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## Introduction & Problem Statement

Hitechdb LLC is an IoT consulting company that designs and deploys IoT monitoring solutions using the Helium network. The first production system (Longview) was deployed in May and initially worked as expected, with sensor data updating on the dashboard at least once per hour. After several weeks, however, there started to be long gaps in time between data updates for sensors on the dashboard. The screenshot below shows an example; specifically sensor TBHH100\_7, which was last updated on the dashboard 14 hours previously and sensor TBHH100\_8 which was last updated on the dashboard 12 hours previously. Both of these sensors are programmed to send a measurement every hour – or more often if temperature or humidity changes occur.

Longview									
Consolidated View    Great Room    East Cabin    North Cabin    Workout Room Air Handler    Attic West Air Handler    Attic East Air Handler    Attic Dehumidifier									
<b>Great Room</b>									
Sensor ID: TBHV110_4	Temperature 3 minutes ago	61 °F	Humidity 3 minutes ago	53 %	Air Quality Status 3 minutes ago	Excellent	Battery Voltage 3 minutes ago	3.5 V	
<b>East Cabin</b>									
Sensor ID: TBHH100_8	Temperature 12 hours ago	61 °F	Humidity 12 hours ago	64 %	Battery Voltage 12 hours ago			3.6 V	
<b>North Cabin</b>									
Sensor ID: TBHH100_7	Temperature 14 hours ago	61 °F	Humidity 14 hours ago	75 %	Battery Voltage 14 hours ago			3.6 V	
<b>Workout Room Air Handler</b>									
Sensor ID: TBWL100_10	Temperature 21 minutes ago	68 °F	Humidity 21 minutes ago	46 %	Water Leak 21 minutes ago	No Leak Detected		Battery Voltage 21 minutes ago	3.6 V
<b>Attic West Air Handler</b>									
Sensor ID: TBWL100_7	Temperature 10 hours ago	70 °F	Humidity 10 hours ago	42 %	Water Leak 10 hours ago	No Leak Detected		Battery Voltage 10 hours ago	3.6 V

One of the purposes of the Longview system is to alert the client to adverse conditions so that corrective/preventative action can be taken. For this reason, a delay of 12 hours is not acceptable as significant property damage could occur during that time.

For example, for the 2 Cabins the sensors are monitoring the conditions inside the cabins. If the cabin’s HVAC system is out of order during the winter and the temperature gets below freezing, pipes may burst. Another example is the water leak sensors on the Air Handlers in the attic of the main house. If there is excessive water build up in the Air Handler drain pans, water could overflow and cause damage to the home’s ceiling.

To understand the root cause of the gaps in sensor data updates on the dashboard, Hitechdb initiated a detailed investigation that involved

- Bringing 2 additional production systems online
- Increasing system data logging capability
- Performing a detailed analysis of the data in the logs
- Documenting the results of the data analysis

This report contains the results of the data analysis and is organized into the following sections:

- Systems Overview: describes the makeup of the 3 systems, including location, sensors, and gateway details
- Systems Performance Summary: describes the overall performance of each of the 3 systems
- Observations: provides a high level summary of observations after reviewing the system and sensor graphs
- Systems Performance Detailed Analysis: performance analysis of each sensor in each system
- Appendix A: performance Measurement Methodology: explains how performance is measured



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- Appendix B: performance graphs for the Longview System
- Appendix C: performance graphs for the Sunrise System
- Appendix D: performance graphs for the Rogers System
- Appendix E: information on the data files used in the analysis

## Systems Overview

Hitechdb has 3 production systems built with Browan sensors. An overview of each production system is provided in the table below. Two of the systems are using Helium’s VIP Console, which is restricted to Helium partners. The other system uses the standard Helium Production Console which is available to all Helium network users.

System Name	Site Description	Helium Console System	Location	System Build Date	System Deploy Date	Sensors	LoRa Gateway(s)
Longview	2500sf home with 2 cabin outbuildings on the property	Production	Starkville, MS	5/10/21	5/24/21	TBHV110_4 TBHH100_7 TBHH100_8 TBWL100_7 TBWL100_8 TBWL100_9 TBWL100_10	restless-champagne-orca
Rogers	2500sf home	VIP	Rogers, AR	8/5/21	8/17/21	TBHV110_5 TBHH100_5 TBWL100_5 TBWL100_6	dizzy-eggplant-corgi (primary) bald-pineapple-wren
Sunrise	2500sf home	VIP	Davis, CA	8/9/21	8/21/21	TBHV110_6 TBHH100_6	best-pearl-aardvark

Table 1 – Hitechdb Systems Overview

# Systems Performance Summary

System performance is measured by packet completion percentage (PC%), which is the percentage of packets sent by the sensors in the system that are received by the Helium network. If every packet sent by the system sensors is received by the Helium network, then the Packet Completion rate for the system is 100%.

$$\text{Packet Completion Percentage} = (\# \text{ Packets Received}) / (\# \text{ Packets Sent})$$

**The Longview, Rogers, and Sunrise systems all show a similar pattern of starting out with PC rate near 100%, then tailing off to 13 or 14% after several weeks of operation.**

Table 2 shows the initial and steady state PC% for each of the three systems. Initial daily PC% is the average performance for the first few weeks the system was online. The steady state daily PC% is the performance of the system after several weeks of operation. The next section of the document has a detailed explanation of how performance is calculated. Table 3 shows the performance over time for each system.

Hitechdb Systems Performance Summary		
System Name	Initial Daily PC%	Steady State Daily PC%
Longview	~100%	~14%
Rogers	~100%	~13%
Sunrise	~100%	~14%

Table 2 – Systems Performance Summary

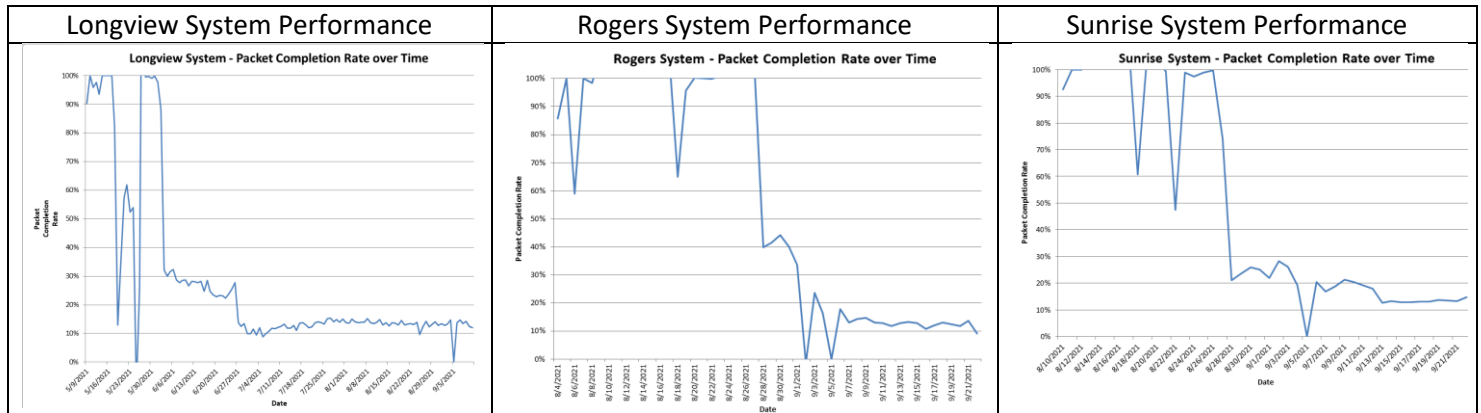


Table 3 – Performance Over Time for the Longview, Rogers, and Sunrise Systems

## Observations

### Packet Completion Rate – System Level

Packet Completion rate for all 3 systems showed the same pattern – starting near 100% then declining to ~13% after a few weeks

- Longview – ~23 days of good performance
- Rogers – ~23 days of good performance
- Sunrise – ~18 days of good performance

## Packet Completion Rate – Per Sensor

Every sensor in each of the 3 systems exhibited a similar pattern. The PC rate would hover near 100% for a period of time, then would drop to and remain under 20%. One sensor, TBHV110\_4 declined over a period of 5-10 days; the rest declined within a span of 1 to 2 days.

The length of time before the PC rate dropped (i.e. the # of days of good performance) varied across the sensors in the system. The sensor with the shortest duration of good performance was sensor TBHV110\_6 in the Sunrise system, with duration of 15 days. The sensor with the longest duration of good performance was sensor TBWL100\_8 in the Longview system with duration of 44 days. The average duration of good performance was 29 days.

### Rogers System Sensors

For the sensors in the Rogers system, the table below shows the date where each sensor’s performance dropped as well as the # of good days of performance.

Rogers System – Key Sensor Dates				
Sensor	Helium Network Activation Date	Deployment Date	Start of Performance Decline	# of Days of Good Performance
TBWL100_5	8/4/21	8/17/21	8/31/21	27
TBWL100_6	8/4/21	8/17/21	8/31/21	27
TBHH100_5	8/3/21	8/17/21	9/3/21	31
TBHV110_5	8/8/21	8/17/21	8/27/21	19

### Sunrise System Sensors

For the sensors in the Sunrise system, the table below shows the date where each sensor’s performance dropped as well as the # of good days of performance.

Sunrise System – Key Sensor Dates				
Sensor	Helium Network Activation Date	Deployment Date	Start of Performance Decline	# of Days of Good Performance
TBHH100_6	8/9/21	8/21/21	9/3/21	25
TBHV110_6	8/12/21	8/21/21	8/27/21	15

### Longview System Sensors

For the sensors in the Longview system, the table below shows the date where each sensor’s performance dropped as well as the # of good days of performance.

Longview System – Key Sensor Dates				
Sensor	Helium Network	Deployment	Start of	# of Days of



	Activation Date	Date	Performance Decline	Good Performance
TBWL100_7	5/11/21	5/24/21	6/6/21	26
TBWL100_8	5/11/21	5/24/21	6/24/21	44
TBWL100_9	5/11/21	5/24/21	5/30/21	19
TBWL100_10	5/12/21	5/24/21	6/3/21	22
TBHH100_7	5/10/21	5/24/21	6/18/21	39
TBHH100_8	5/10/21	5/24/21	6/26/21	47
TBHV110_4	5/8/21	5/24/21	6/25/21	48

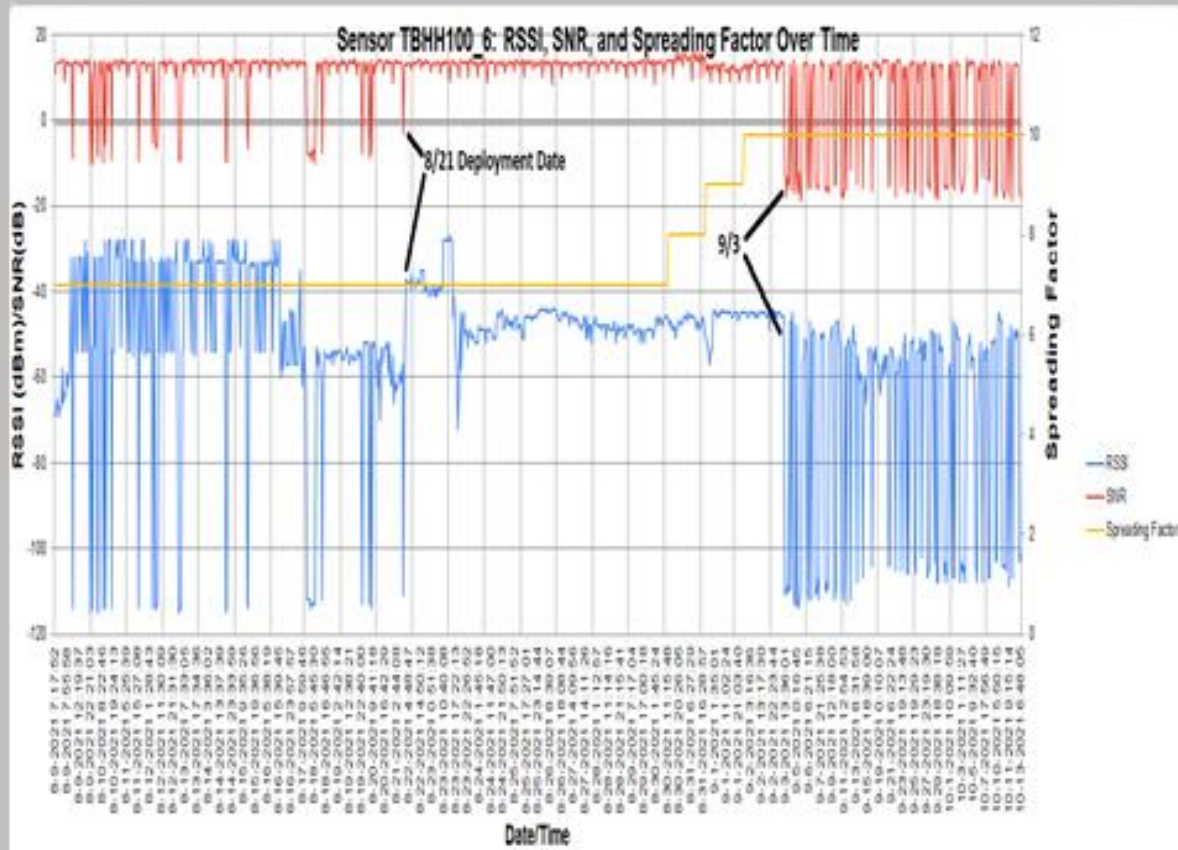
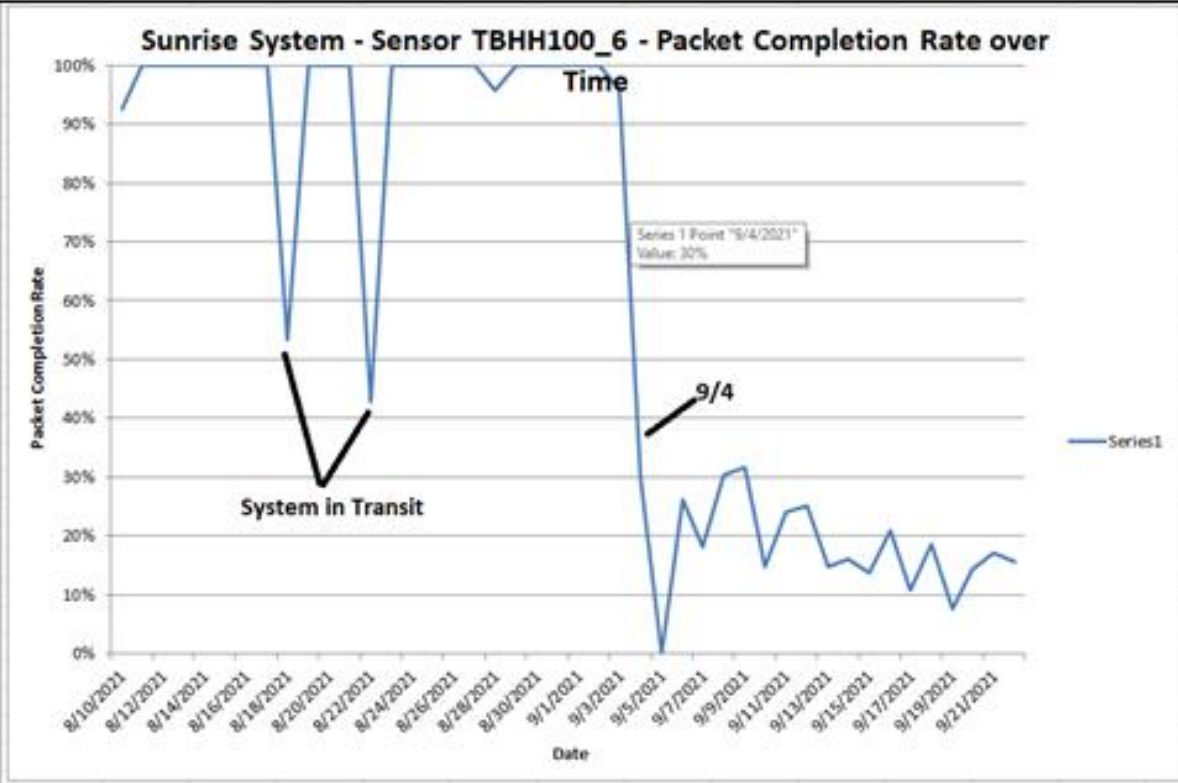
## Spreading Factor Analysis

When looking at RSSI, SNR, and Spreading Factor (SF) data from the sensor logs, a strong correlation is seen between the SF value and the packet completion rate. Specifically, the following two observations apply to every sensor in the Rogers and Sunrise systems:

- When the sensor is activated, the SF starts at 7 then over time increments to 10
- Shortly after achieving a spreading factor of 10, the packet completion rate drops dramatically

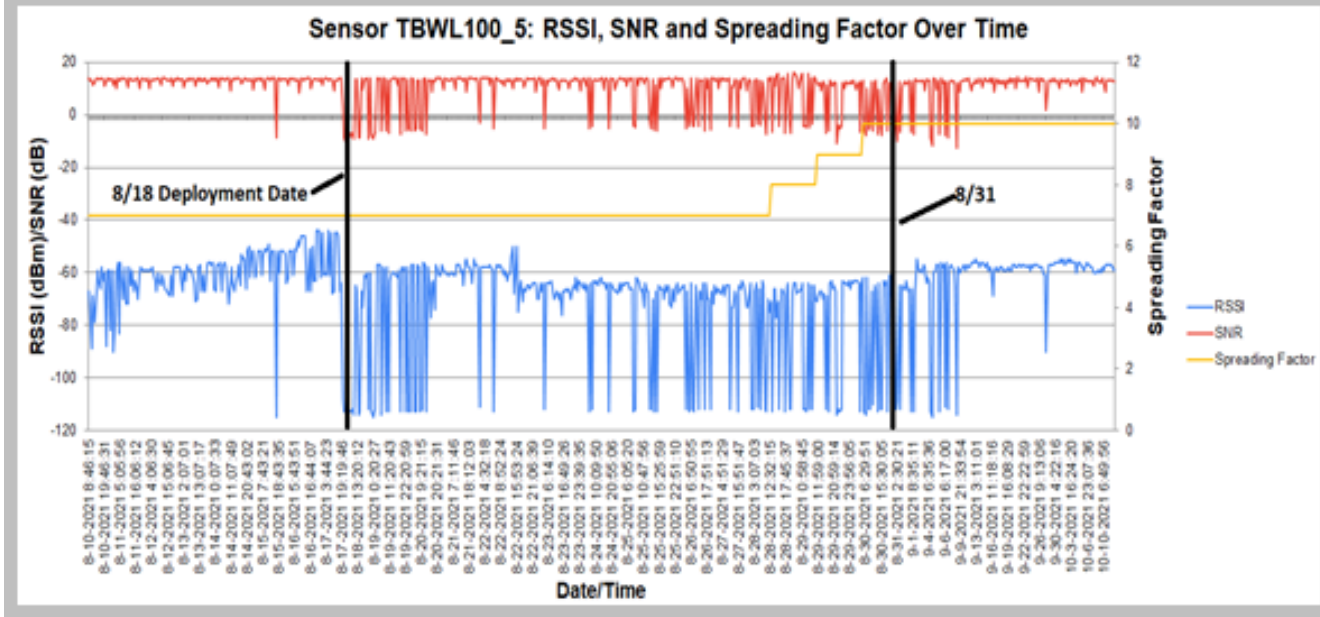
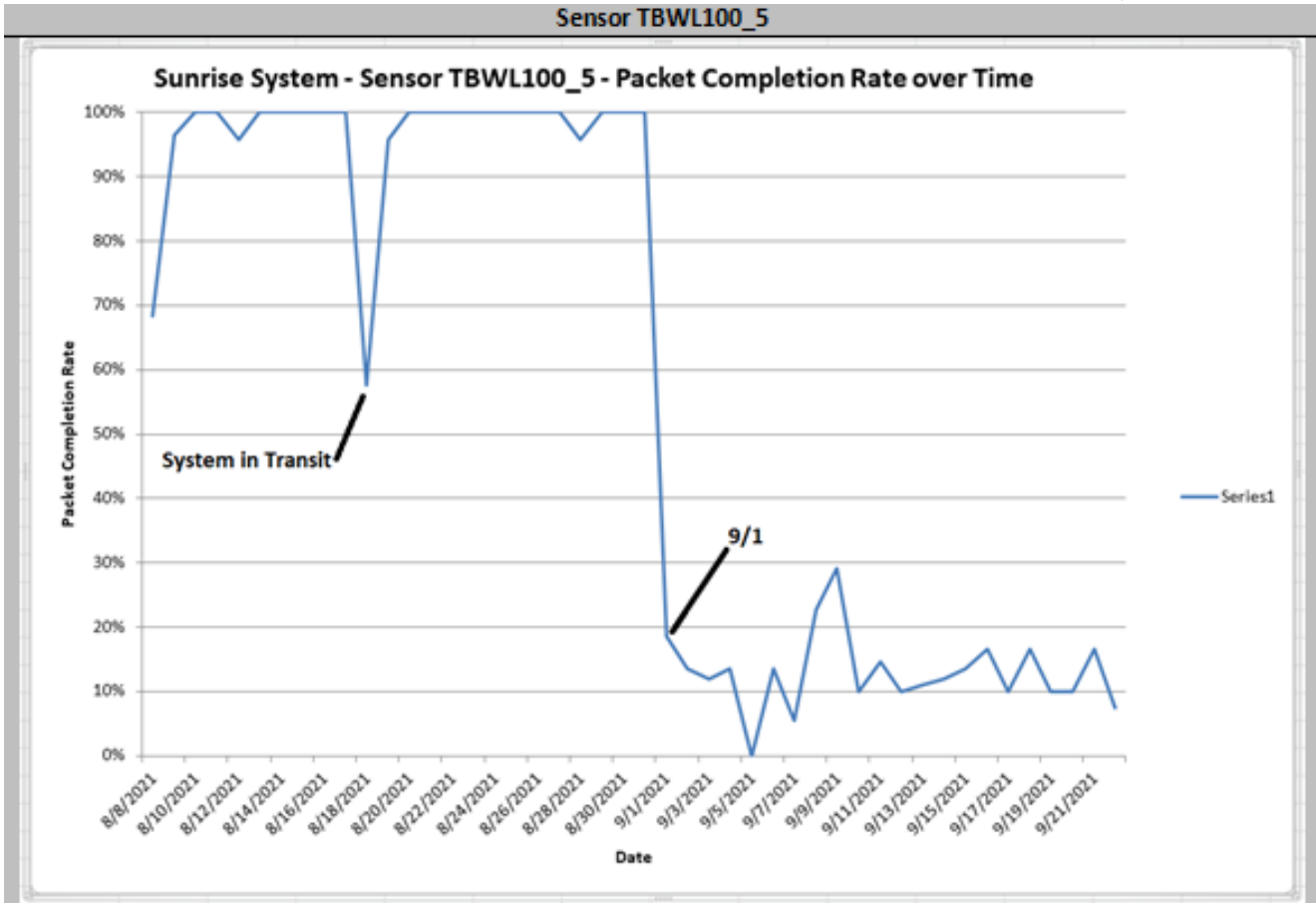
The charts below for sensor TBHH100\_6 are an example of this phenomenon.

The observations most likely apply to the sensors in the Longview system, but because spreading factor was not being captured in the logs for the first few months of operation, there is SF data to analyze



For most, but not all sensors, the RSSI and SNR performance degrades shortly after the spreading factor reaches 10. The charts above for sensor TBHH100\_6 demonstrate this phenomenon.

The charts below for sensor TBWL100\_5 show a sensor where the RSSI and SNR performance does not degrade once the spreading factor reaches 10.



## Systems Performance Detailed Analysis

### Longview System Performance over Time

Chart 1 shows the aggregate PC% for the sensors in the Longview system. The system was constructed in Dacula, GA between 5/10 and 5/19, and then was transported to and deployed in Starkville, MS on 5/24.

From the time the system was constructed up through the first week of deployment (i.e. from 5/10 – 5/30), with the exception of the week of 5/19-5/25 when the Helium Network was having trouble, the PC rate was near 100%.

**After starting with a PC rate near 100% on 5/10, the rate started trending downward from 6/2 – 6/27 after which the PC rate settled out at around 14%.**

The Longview system is located in Starkville, MS and is served by RAK hotspot, restless-champagne-orca, which is located at the site and was deployed on the same date as the sensors. Restless-champagne-orca was initially set up and synchronized to the Helium blockchain on 5/19 in Dacula, GA, then transported along with the sensors to the Longview site on 5/24. The hotspot maintained synch with the blockchain during transport.

The log file, *20211019\_Log\_Longview\_SensorDataFlow.xlsx*, shows the Longview sensor data received through the Helium network. Included in the data log is the hotspot name that transmitted the data (column F). The log shows that all sensors in the Longview system flow through restless-champagne-orca. You can see this in Screenshot 1 (below). Note that the Longview log was not set up until July, so does not contain data during the system setup and initial deployment.

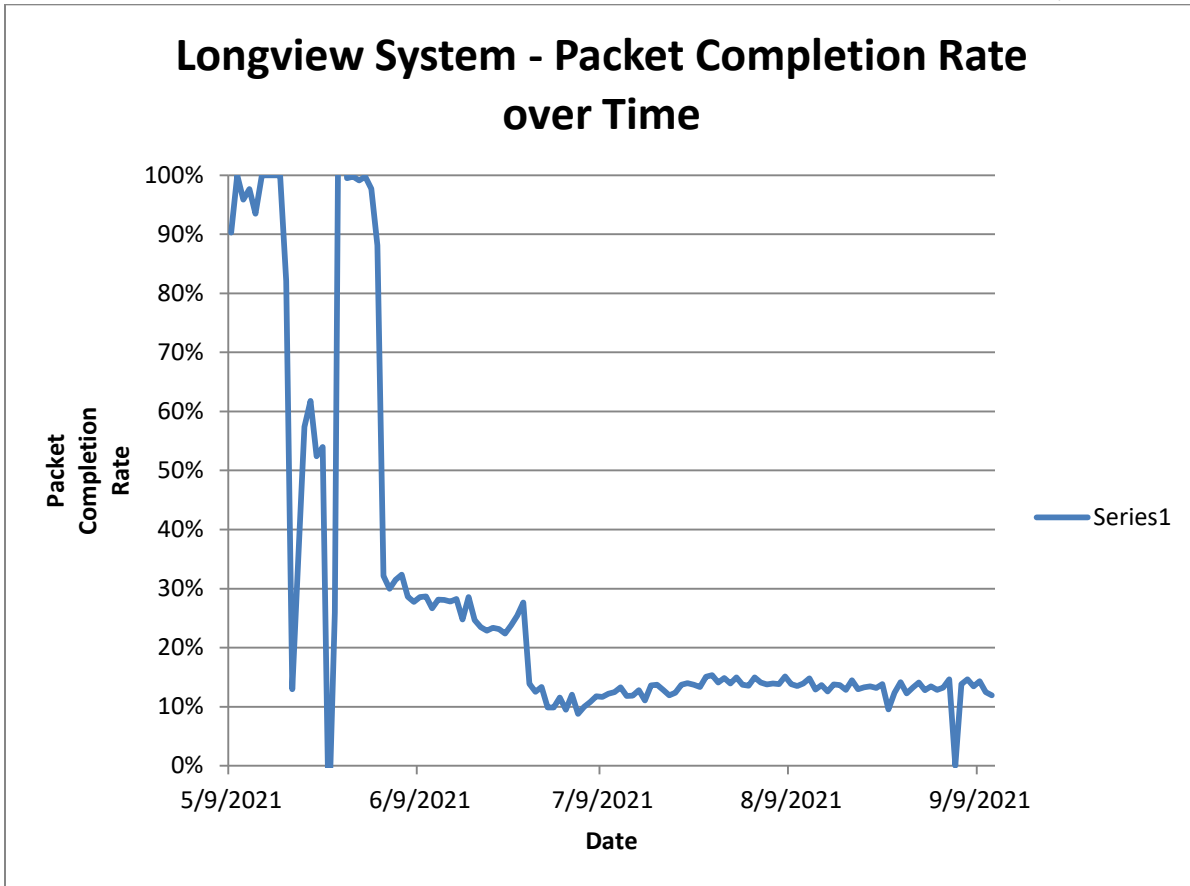


Chart 1 – Longview Packet Completion Rate over time  
 (Chart taken from the 'Longview Performance' tab in 20210911\_Hotspot and DC Tracker.xlsx)

UTC Time	(America/NewYork)	(Local Time)	From Device	Frame Count	Hotspot	Channel	Frequency	Hold Time	RSSI	SNR	Spreading
7-9-2021 19:42:41	7-9-2021 15:42:42	7-9-2021 15:42:35	TBHV110_4	13259	restless-champagne-orca	11	904.5	1490	-89	11.50	SF10BW125
7-9-2021 19:47:40	7-9-2021 15:47:41	7-9-2021 15:47:35	TBHV110_4	13260	restless-champagne-orca	12	904.7000122	842	-88	11.80	SF10BW125
7-9-2021 20:27:56	7-9-2021 16:27:56	7-9-2021 16:27:54	TBWL100_8	1457	restless-champagne-orca	9	904.0999756	1578	-54	12.80	SF10BW125
7-9-2021 21:17:43	7-9-2021 17:17:43	7-9-2021 17:17:37	TBHV110_4	13278	restless-champagne-orca	8	903.9000244	1765	-93	10.00	SF10BW125
7-9-2021 23:07:48	7-9-2021 19:07:48	7-9-2021 19:07:41	TBHV110_4	13286	restless-champagne-orca	10	904.2999878	4205342	-94	9.50	SF10BW125
7-10-2021 0:22:46	7-9-2021 20:22:46	7-9-2021 20:22:40	TBHV110_4	13315	restless-champagne-orca	9	904.0999756	1382	-89	11.00	SF10BW125
7-10-2021 1:02:48	7-9-2021 21:02:48	7-9-2021 21:02:41	TBHV110_4	13317	restless-champagne-orca	15	905.2999878	1476	-88	11.50	SF10BW125
7-10-2021 1:07:47	7-9-2021 21:07:47	7-9-2021 21:07:41	TBHV110_4	13323	restless-champagne-orca	11	904.5	1833	-90	10.50	SF10BW125
7-10-2021 2:37:48	7-9-2021 22:37:48	7-9-2021 22:37:42	TBHV110_4	13324	restless-champagne-orca	12	904.7000122	1504	-90	10.80	SF10BW125
7-10-2021 2:37:48	7-9-2021 22:37:48	7-9-2021 22:37:42	TBHV110_4	13342	restless-champagne-orca	8	903.9000244	728	-91	11.50	SF10BW125
7-10-2021 3:16:27	7-9-2021 23:16:27	7-9-2021 23:16:26	TBHH100_8	2033	restless-champagne-orca	9	904.0999756	1608	-97	9.50	SF10BW125
7-10-2021 3:17:48	7-9-2021 23:17:49	7-9-2021 23:17:43	TBHV110_4	13350	restless-champagne-orca	10	904.2999878	964	-91	9.80	SF10BW125
7-10-2021 3:37:26	7-9-2021 23:37:26	7-9-2021 23:37:25	TBHH100_8	2035	restless-champagne-orca	15	905.2999878	1460	-96	11.00	SF10BW125
7-10-2021 4:27:51	7-10-2021 0:27:51	7-10-2021 0:27:44	TBHV110_4	13364	restless-champagne-orca	14	905.0999756	1722	-87	11.50	SF10BW125
7-10-2021 4:39:21	7-10-2021 0:39:22	7-10-2021 0:39:20	TBHH100_8	2041	restless-champagne-orca	11	904.5	1437	-95	9.80	SF10BW125
7-10-2021 5:42:47	7-10-2021 1:42:47	7-10-2021 1:42:46	TBHH100_8	2042	restless-champagne-orca	12	904.7000122	1889634	-96	8.80	SF10BW125
7-10-2021 5:42:47	7-10-2021 1:42:48	7-10-2021 1:42:46	TBWL100_8	1466	restless-champagne-orca	12	904.7000122	880881	-54	12.50	SF10BW125
7-10-2021 5:42:52	7-10-2021 1:42:52	7-10-2021 1:42:46	TBHV110_4	13379	restless-champagne-orca	9	904.0999756	2074	-91	11.50	SF10BW125
7-10-2021 5:46:40	7-10-2021 1:46:40	7-10-2021 1:46:38	TBWL100_10	1465	restless-champagne-orca	14	905.0999756	1267	-67	13.00	SF10BW125
7-10-2021 5:52:52	7-10-2021 1:52:53	7-10-2021 1:52:46	TBHV110_4	13381	restless-champagne-orca	15	905.2999878	1895	-87	11.20	SF10BW125
7-10-2021 6:22:55	7-10-2021 2:22:55	7-10-2021 2:22:48	TBHV110_4	13387	restless-champagne-orca	11	904.5	3527	-91	10.20	SF10BW125
7-10-2021 6:27:52	7-10-2021 2:27:53	7-10-2021 2:27:46	TBHV110_4	13388	restless-champagne-orca	12	904.7000122	1442	-90	10.50	SF10BW125
7-10-2021 6:47:58	7-10-2021 2:47:59	7-10-2021 2:47:57	TBWL100_7	1461	restless-champagne-orca	9	904.0999756	1529	-64	13.20	SF10BW125
7-10-2021 7:15:08	7-10-2021 3:15:08	7-10-2021 3:15:06	TBWL100_9	1445	restless-champagne-orca	8	903.9000244	1506	-90	11.00	SF10BW125
7-10-2021 7:57:54	7-10-2021 3:57:55	7-10-2021 3:57:48	TBHV110_4	13406	restless-champagne-orca	8	903.9000244	1736	-92	11.00	SF10BW125
7-10-2021 9:47:52	7-10-2021 5:47:53	7-10-2021 5:47:50	TBWL100_7	1463	restless-champagne-orca	15	905.2999878	3591798	-64	13.00	SF10BW125
7-10-2021 9:47:56	7-10-2021 5:47:56	7-10-2021 5:47:50	TBHV110_4	13414	restless-champagne-orca	10	904.2999878	4202822	-90	9.20	SF10BW125
7-10-2021 9:48:03	7-10-2021 5:48:03	7-10-2021 5:47:50	TBHV110_4	13418	restless-champagne-orca	13	904.9000244	3002759	-87	11.00	SF10BW125
7-10-2021 9:48:09	7-10-2021 5:48:10	7-10-2021 5:47:50	TBHV110_4	13428	restless-champagne-orca	14	905.0999756	2052	-88	12.00	SF10BW125
7-10-2021 11:02:58	7-10-2021 7:02:58	7-10-2021 7:02:51	TBHV110_4	13443	restless-champagne-orca	9	904.0999756	1534	-92	10.50	SF10BW125
7-10-2021 11:13:01	7-10-2021 7:13:02	7-10-2021 7:12:55	TBHV110_4	13445	restless-champagne-orca	15	905.2999878	5496	-87	11.00	SF10BW125
7-10-2021 11:42:57	7-10-2021 7:42:58	7-10-2021 7:42:52	TBHV110_4	13451	restless-champagne-orca	11	904.5	1377	-90	10.50	SF10BW125
7-10-2021 13:17:59	7-10-2021 9:18:00	7-10-2021 9:17:53	TBHV110_4	13452	restless-champagne-orca	12	904.7000122	5402903	-91	11.20	SF10BW125
7-10-2021 13:18:06	7-10-2021 9:18:07	7-10-2021 9:17:53	TBHV110_4	13470	restless-champagne-orca	8	903.9000244	1484	-92	11.00	SF10BW125
7-10-2021 13:58:01	7-10-2021 9:58:01	7-10-2021 9:57:54	TBHV110_4	13478	restless-champagne-orca	10	904.2999878	1541	-92	9.80	SF10BW125
7-10-2021 14:18:03	7-10-2021 10:18:04	7-10-2021 10:17:55	TBHV110_4	13482	restless-champagne-orca	13	904.9000244	1418	-95	10.20	SF10BW125
7-10-2021 14:48:10	7-10-2021 10:48:10	7-10-2021 10:48:09	TBWL100_7	1469	restless-champagne-orca	11	904.5	1546	-67	11.50	SF10BW125
7-10-2021 15:08:01	7-10-2021 11:08:02	7-10-2021 11:07:55	TBHV110_4	13492	restless-champagne-orca	14	905.0999756	1429	-88	12.20	SF10BW125

Screenshot 1 – Sensor Data from the Longview System  
 (Screenshot taken from the 'LongviewData' tab in 20211019\_Log\_Longview\_SensorDataFlow.xlsx)

## Rogers System Performance over Time

Chart 2 shows the aggregate PC% for the sensors in the Rogers system. The system was constructed in Dacula, GA between 8/5 – 8/7, and then was transported to and deployed in Rogers, AR on 8/17.

From the time the system was constructed up through the first week of deployment (i.e. from 8/7 – 8/27), the PC% was near 100%. The PC% dip on 8/18 is due to the system being transported on 8/17.

**After starting with a PC rate near 100% on 8/5, the rate started trending downward from 8/28 – 9/7 after which the rate settled out at around 13%.**

The Rogers system is located in Rogers, AR and is served primarily by RAK hotspot, dizzy-eggplant-corgi, which is located at the site and was deployed on the same date as the sensors. Dizzy-eggplant-corgi was initially set up and synchronized to the Helium blockchain between 8/5 and 8/7 in Dacula, GA, then transported to Rogers, AR on 8/17. The hotspot resynched with the Helium blockchain on 8/18.

The log file, *20211012\_Log\_RogersHome\_SensorDataFlow.xlsx*, shows the system sensor data received through the Helium network. Included in the data log is the hotspot name that transmitted the data (column F). The log shows that once the hotspot completed synching on 8/18, most of the sensor data flows through dizzy-eggplant-corgi. You can see this in Screenshot 2 (below).

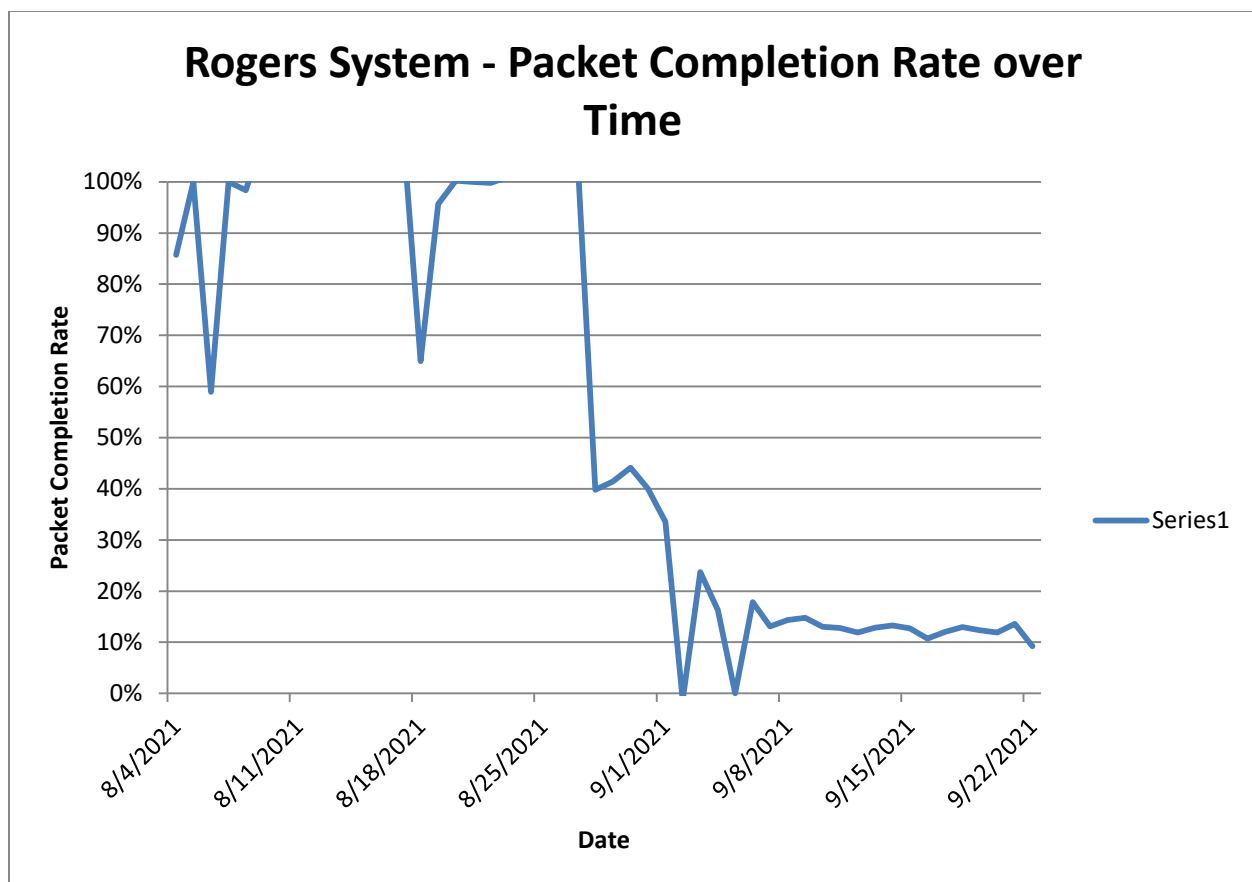


Chart 2 – Rogers Packet Completion Rate over time  
 (Chart taken from the 'Rogers System Performance' tab in *20210922\_Hotspot and DC Tracker - VIP.xlsx*)

1	A	B	C	D	E	F	G	H	I	J	K	L
UTC Time	(America/NewYork)	(Local Time)	From Device	Frame Count	Hotspot	Channel	Frequency	Hold Time	RSSI	SNR	Spreading	
3188	8-18-2021 15:57:24	8-18-2021 11:57:24	8-18-2021 11:57:23	TBHV110_5	2889	dizzy-eggplant-corgi	8	903.9000244	719	-65	14.20	SF8BW125
3189	8-18-2021 16:02:31	8-18-2021 12:02:32	8-18-2021 12:02:30	TBHH100_5	412	dizzy-eggplant-corgi	11	904.5	208	-70	13.20	SF7BW125
3190	8-18-2021 16:02:35	8-18-2021 12:02:35	8-18-2021 12:02:23	TBHV110_5	2890	dizzy-eggplant-corgi	10	904.2999878	196	-66	11.00	SF8BW125
3191	8-18-2021 16:07:23	8-18-2021 12:07:24	8-18-2021 12:07:23	TBHV110_5	2891	dizzy-eggplant-corgi	13	904.9000244	200	-65	14.20	SF8BW125
3192	8-18-2021 16:10:28	8-18-2021 12:10:28	8-18-2021 12:10:27	TBWL100_6	276	dizzy-eggplant-corgi	15	905.2999878	203	-72	13.20	SF7BW125
3193	8-18-2021 16:12:24	8-18-2021 12:12:24	8-18-2021 12:12:23	TBHV110_5	2892	dizzy-eggplant-corgi	14	905.0999756	296	-68	15.80	SF8BW125
3194	8-18-2021 16:17:24	8-18-2021 12:17:24	8-18-2021 12:17:23	TBHV110_5	2893	dizzy-eggplant-corgi	9	904.0999756	243	-66	13.80	SF8BW125
3195	8-18-2021 16:20:09	8-18-2021 12:20:10	8-18-2021 12:20:08	TBWL100_5	273	dizzy-eggplant-corgi	15	905.2999878	201	-67	13.50	SF7BW125
3196	8-18-2021 16:22:24	8-18-2021 12:22:24	8-18-2021 12:22:23	TBHV110_5	2894	dizzy-eggplant-corgi	15	905.2999878	201	-70	14.20	SF8BW125
3197	8-18-2021 16:27:24	8-18-2021 12:27:24	8-18-2021 12:27:23	TBHV110_5	2895	dizzy-eggplant-corgi	11	904.5	213	-67	13.50	SF8BW125
3198	8-18-2021 16:32:24	8-18-2021 12:32:25	8-18-2021 12:32:23	TBHV110_5	2896	bald-pineapple-wren	12	904.7000122	508	-112	-8.80	SF8BW125
3199	8-18-2021 16:37:24	8-18-2021 12:37:24	8-18-2021 12:37:23	TBHV110_5	2897	dizzy-eggplant-corgi	8	903.9000244	268	-66	14.00	SF8BW125
3200	8-18-2021 16:42:25	8-18-2021 12:42:26	8-18-2021 12:42:24	TBHV110_5	2898	dizzy-eggplant-corgi	10	904.2999878	566	-66	10.80	SF8BW125
3201	8-18-2021 16:47:24	8-18-2021 12:47:25	8-18-2021 12:47:23	TBHV110_5	2899	dizzy-eggplant-corgi	13	904.9000244	259	-68	14.20	SF8BW125
3202	8-18-2021 16:52:24	8-18-2021 12:52:25	8-18-2021 12:52:23	TBHV110_5	2900	dizzy-eggplant-corgi	14	905.0999756	255	-72	13.80	SF8BW125
3203	8-18-2021 16:57:25	8-18-2021 12:57:25	8-18-2021 12:57:24	TBHV110_5	2901	dizzy-eggplant-corgi	9	904.0999756	913	-67	16.00	SF8BW125
3204	8-18-2021 17:02:25	8-18-2021 13:02:25	8-18-2021 13:02:24	TBHV110_5	2902	bald-pineapple-wren	15	905.2999878	528	-113	-9.20	SF8BW125
3205	8-18-2021 17:02:40	8-18-2021 13:02:41	8-18-2021 13:02:40	TBHH100_5	413	dizzy-eggplant-corgi	12	904.7000122	268	-69	13.00	SF7BW125
3206	8-18-2021 17:07:24	8-18-2021 13:07:25	8-18-2021 13:07:24	TBHV110_5	2903	dizzy-eggplant-corgi	11	904.5	286	-67	14.00	SF8BW125
3207	8-18-2021 17:10:29	8-18-2021 13:10:30	8-18-2021 13:10:28	TBWL100_6	277	dizzy-eggplant-corgi	11	904.5	270	-71	14.20	SF7BW125
3208	8-18-2021 17:12:25	8-18-2021 13:12:25	8-18-2021 13:12:24	TBHV110_5	2904	dizzy-eggplant-corgi	12	904.7000122	263	-70	15.80	SF8BW125
3209	8-18-2021 17:17:25	8-18-2021 13:17:25	8-18-2021 13:17:24	TBHV110_5	2905	dizzy-eggplant-corgi	8	903.9000244	265	-65	16.00	SF8BW125
3210	8-18-2021 17:20:11	8-18-2021 13:20:12	8-18-2021 13:20:10	TBWL100_5	274	bald-pineapple-wren	11	904.5	557	-114	-8.50	SF7BW125
3211	8-18-2021 17:22:25	8-18-2021 13:22:25	8-18-2021 13:22:24	TBHV110_5	2906	dizzy-eggplant-corgi	10	904.2999878	265	-65	11.80	SF8BW125
3212	8-18-2021 17:27:25	8-18-2021 13:27:26	8-18-2021 13:27:24	TBHV110_5	2907	dizzy-eggplant-corgi	13	904.9000244	268	-71	14.20	SF8BW125
3213	8-18-2021 17:32:25	8-18-2021 13:32:26	8-18-2021 13:32:25	TBHV110_5	2908	dizzy-eggplant-corgi	14	905.0999756	808	-65	14.00	SF8BW125
3214	8-18-2021 17:37:25	8-18-2021 13:37:26	8-18-2021 13:37:24	TBHV110_5	2909	dizzy-eggplant-corgi	9	904.0999756	283	-66	13.80	SF8BW125
3215	8-18-2021 17:42:25	8-18-2021 13:42:26	8-18-2021 13:42:24	TBHV110_5	2910	dizzy-eggplant-corgi	15	905.2999878	337	-70	14.20	SF8BW125
3216	8-18-2021 17:47:26	8-18-2021 13:47:26	8-18-2021 13:47:25	TBHV110_5	2911	dizzy-eggplant-corgi	11	904.5	576	-64	14.00	SF8BW125
3217	8-18-2021 17:52:25	8-18-2021 13:52:26	8-18-2021 13:52:24	TBHV110_5	2912	dizzy-eggplant-corgi	12	904.7000122	281	-66	14.00	SF8BW125
3218	8-18-2021 17:57:26	8-18-2021 13:57:27	8-18-2021 13:57:25	TBHV110_5	2913	dizzy-eggplant-corgi	8	903.9000244	914	-62	14.00	SF8BW125

Screenshot 2 – Sensor Data from the Rogers System  
 (Screenshot taken from the 'RogersData' tab in 20211012\_Log\_RogersHome\_SensorDataFlow.xlsx)

1

## Sunrise System Performance over Time

Chart 3 shows the aggregate PC% for the sensors in the Sunrise system. The system was constructed in Dacula, GA between 8/9 and 8/11, with the sensors transported to Rogers, AR on 8/17, and then transported to and deployed in Davis, CA on 8/21.

From the time the system was constructed up through the first week of deployment in Davis, CA (i.e. from 8/11 – 8/27), the PC% was near 100%. The PC% dips on 8/18 and 8/22 are due to the system being transported.

**After starting with a PC rate near 100% on 8/9, the rate started trending downward from 8/28 – 9/13 after which the rate settled out at around 13%.**

The Sunrise system is located in Davis, CA and is served by a single by RAK hotspot, best-pearl-aardvark, which is located at the Sunrise site. Best-pearl-aardvark was initially set up and synchronized to the Helium blockchain in July in Dacula, GA. The hotspot was sent to Davis CA on 8/3, then setup and resynched to the Helium blockchain on 8/17. The sensors were deployed in Davis on 8/21.

The log file, 20211013\_Log\_SunriseFamilyFarm\_SensorDataFlow.xlsx, shows the system sensor data received through the Helium network. Included in the data log is the hotspot name that transmitted the data (column F). The log shows that once the sensors were deployed in Davis late in the day on 8/21, all sensor data is flowing through hotspot best-pearl-aardvark. You can see this in Screenshot 3 (below).



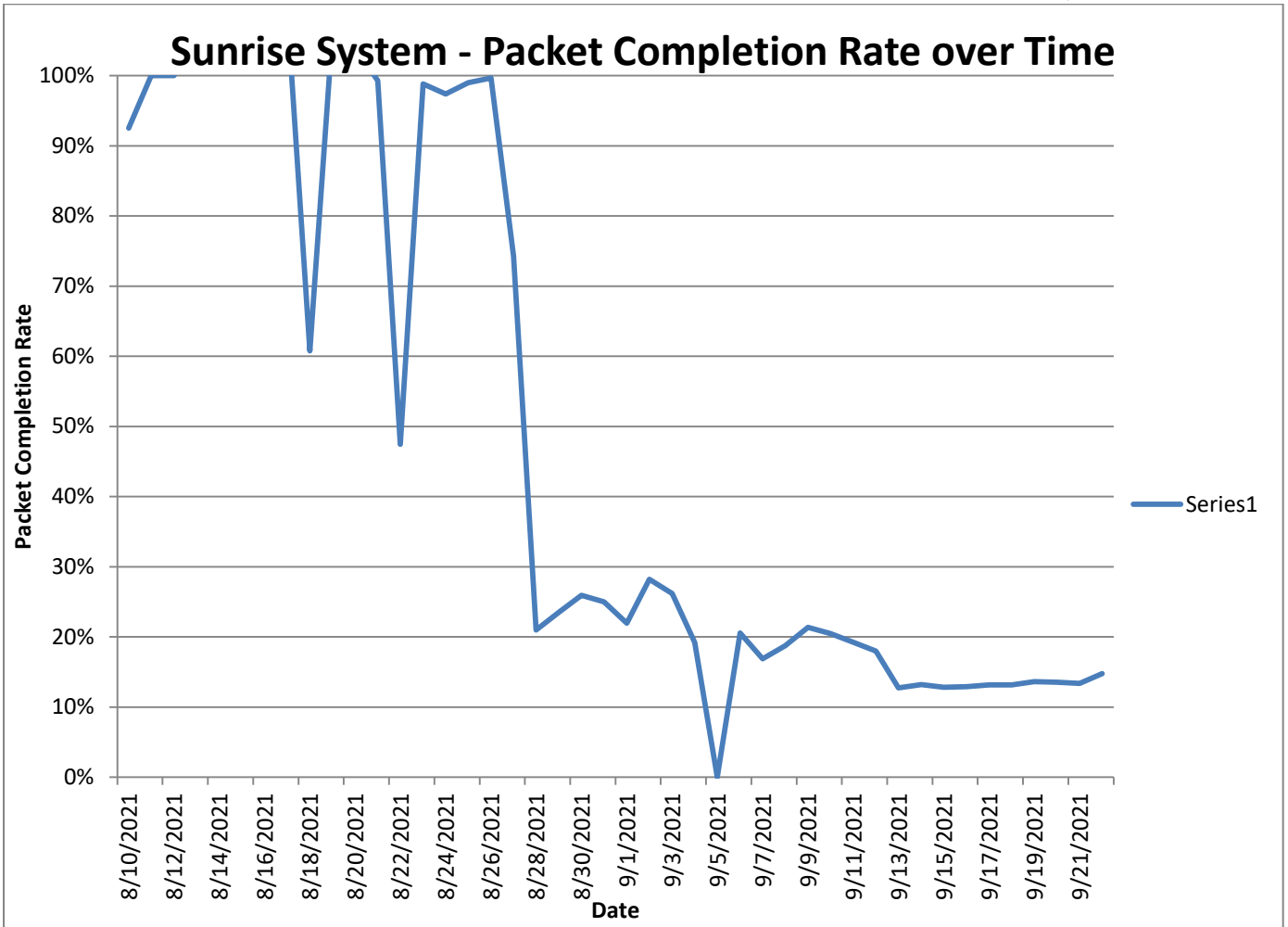


Chart 3 – Sunrise Packet Completion Rate over time

(Chart taken from the 'Sunrise System Performance' tab in 20210922\_Hotspot and DC Tracker - VIP.xlsx)

Log\_SunriseFamilyFarm\_SensorDataFlow ☆ 📄 🌐

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UTC Time													
1	A	B	C	D	E	F	G	H	I	J	K	L	M
UTC Time	Local Time (America/NewYork)	Reported At (Local Time)	From Device	Frame Count	Hotspot	Channel	Frequency	Hold Time	RSSI	SNR	Spreading	Hotspot Status	
6751	8-23-2021 15:57:03	8-23-2021 11:57:04	8-23-2021 11:57:02	TBHV110_6	3112	best-pearl-aardvark	15	905.2999878	597	-41	14.20	SF8BW125	success
6752	8-23-2021 16:02:04	8-23-2021 12:02:04	8-23-2021 12:02:02	TBHV110_6	3113	best-pearl-aardvark	11	904.5	446	-39	15.20	SF8BW125	success
6753	8-23-2021 16:07:03	8-23-2021 12:07:04	8-23-2021 12:07:02	TBHV110_6	3114	best-pearl-aardvark	12	904.7000122	443	-40	14.50	SF8BW125	success
6754	8-23-2021 16:12:03	8-23-2021 12:12:04	8-23-2021 12:12:02	TBHV110_6	3115	best-pearl-aardvark	8	903.9000244	447	-40	15.20	SF8BW125	success
6755	8-23-2021 16:17:03	8-23-2021 12:17:04	8-23-2021 12:17:03	TBHV110_6	3116	best-pearl-aardvark	10	904.2999878	448	-40	12.50	SF8BW125	success
6756	8-23-2021 16:22:04	8-23-2021 12:22:05	8-23-2021 12:22:03	TBHV110_6	3117	best-pearl-aardvark	13	904.9000244	672	-40	14.00	SF8BW125	success
6757	8-23-2021 16:27:05	8-23-2021 12:27:05	8-23-2021 12:27:03	TBHV110_6	3118	best-pearl-aardvark	14	905.0999756	448	-40	14.50	SF8BW125	success
6758	8-23-2021 16:32:04	8-23-2021 12:32:05	8-23-2021 12:32:03	TBHV110_6	3119	best-pearl-aardvark	9	904.0999756	467	-39	15.50	SF8BW125	success
6759	8-23-2021 16:37:04	8-23-2021 12:37:05	8-23-2021 12:37:03	TBHV110_6	3120	best-pearl-aardvark	15	905.2999878	801	-41	14.00	SF8BW125	success
6760	8-23-2021 16:42:05	8-23-2021 12:42:06	8-23-2021 12:42:04	TBHV110_6	3121	best-pearl-aardvark	11	904.5	1728	-40	16.00	SF8BW125	success
6761	8-23-2021 16:47:04	8-23-2021 12:47:05	8-23-2021 12:47:03	TBHV110_6	3122	best-pearl-aardvark	12	904.7000122	1009	-40	14.00	SF8BW125	success
6762	8-23-2021 16:50:29	8-23-2021 12:50:30	8-23-2021 12:50:28	TBHV110_6	369	best-pearl-aardvark	12	904.7000122	500	-28	13.80	SF7BW125	success
6763	8-23-2021 16:52:05	8-23-2021 12:52:05	8-23-2021 12:52:04	TBHV110_6	3123	best-pearl-aardvark	8	903.9000244	823	-40	16.00	SF8BW125	success
6764	8-23-2021 16:53:03	8-23-2021 12:53:03	8-23-2021 12:53:02	BOL_4	397	best-pearl-aardvark	8	903.9000244	188	-49	14.20	SF10BW125	success
6765	8-23-2021 16:53:19	8-23-2021 12:53:20	8-23-2021 12:53:18	BOL_4	398	best-pearl-aardvark	10	904.2999878	346	-58	10.80	SF10BW125	success
6766	8-23-2021 16:53:35	8-23-2021 12:53:35	8-23-2021 12:53:34	BOL_4	399	best-pearl-aardvark	13	904.9000244	195	-59	14.00	SF10BW125	success
6767	8-23-2021 16:53:51	8-23-2021 12:53:52	8-23-2021 12:53:50	BOL_4	400	best-pearl-aardvark	14	905.0999756	346	-59	14.00	SF10BW125	success
6768	8-23-2021 16:54:07	8-23-2021 12:54:07	8-23-2021 12:54:06	BOL_4	401	best-pearl-aardvark	9	904.0999756	210	-57	13.80	SF10BW125	success
6769	8-23-2021 16:54:20	8-23-2021 12:54:21	8-23-2021 12:54:19	BOL_4	402	best-pearl-aardvark	15	905.2999878	181	-60	13.80	SF10BW125	success
6770	8-23-2021 16:57:04	8-23-2021 12:57:05	8-23-2021 12:57:03	TBHV110_6	3124	best-pearl-aardvark	10	904.2999878	669	-40	13.00	SF8BW125	success
6771	8-23-2021 17:02:05	8-23-2021 13:02:05	8-23-2021 13:02:04	TBHV110_6	3125	best-pearl-aardvark	13	904.9000244	737	-40	14.50	SF8BW125	success
6772	8-23-2021 17:07:05	8-23-2021 13:07:05	8-23-2021 13:07:04	TBHV110_6	3126	best-pearl-aardvark	14	905.0999756	843	-41	14.00	SF8BW125	success
6773	8-23-2021 17:12:06	8-23-2021 13:12:06	8-23-2021 13:12:05	TBHV110_6	3127	best-pearl-aardvark	9	904.0999756	1693	-40	14.20	SF8BW125	success
6774	8-23-2021 17:17:05	8-23-2021 13:17:06	8-23-2021 13:17:04	TBHV110_6	3128	best-pearl-aardvark	15	905.2999878	1552	-42	15.80	SF8BW125	success
6775	8-23-2021 17:22:05	8-23-2021 13:22:06	8-23-2021 13:22:04	TBHV110_6	3129	best-pearl-aardvark	11	904.5	753	-40	14.80	SF8BW125	success
6776	8-23-2021 17:27:05	8-23-2021 13:27:05	8-23-2021 13:27:04	TBHV110_6	3130	best-pearl-aardvark	12	904.7000122	797	-40	14.20	SF8BW125	success
6777	8-23-2021 17:32:05	8-23-2021 13:32:06	8-23-2021 13:32:04	TBHV110_6	3131	best-pearl-aardvark	8	903.9000244	541	-40	14.80	SF8BW125	success
6778	8-23-2021 17:37:05	8-23-2021 13:37:06	8-23-2021 13:37:04	TBHV110_6	3132	best-pearl-aardvark	10	904.2999878	863	-40	11.20	SF8BW125	success
6779	8-23-2021 17:42:05	8-23-2021 13:42:06	8-23-2021 13:42:04	TBHV110_6	3133	best-pearl-aardvark	13	904.9000244	475	-40	14.00	SF8BW125	success
6780	8-23-2021 17:47:05	8-23-2021 13:47:06	8-23-2021 13:47:04	TBHV110_6	3134	best-pearl-aardvark	14	905.0999756	489	-41	14.20	SF8BW125	success

Screenshot 3 – Sensor Data from the Sunrise System  
 (Screenshot taken from the 'Data' tab in 20211013\_Log\_SunriseFamilyFarm\_SensorDataFlow.xlsx)

## Appendix A - Performance Measurement Methodology

System performance is calculated by summing the performance of each sensor in the system. Sensor performance is measured by packet completion (PC) rate, which is the ratio of the number of packets sent by a sensor in a given time period to the number of packets received by the Helium network for that sensor in the same time period. A PC rate of 100% means that every packet sent by the sensor is received by the Helium network.

$$\text{Packet Completion Rate} = (\# \text{ Packets Received}) / (\# \text{ Packets Sent})$$

$$\text{Daily Packet Completion Percentage} = (\# \text{ Packets Received in the last 24 hours}) / (\# \text{ Packets Sent in the last 24 hours})$$

The number of packets sent by a sensor in a given period can be calculated using the Frame Count information in the Helium Console (see Screenshot 1). Specifically, the number of packets sent by the sensor for a given period is the difference between the sensor’s Frame Up values at the end and the start of the period.

Similarly, the number of packets received by the Helium network from a sensor in a given period is calculated using the Packets Transferred information in the Helium Console (see Screenshot 1). Specifically, the number of packets received from a sensor for a given period is the difference between the sensor’s Packets Transferred values at the end and the start of the period.

Device Name	Device EUI	Labels	Frame Up	Frame Down	Packets Transferred	DC Used	Date Activated	Last Connected
BOL_4	584BC8000202400	CUS_SF	1651	767	4516	4516	Aug 5, 2021 7:40 AM	Sep 9, 2021 2:38 AM
Gary's BOL	584BC8000202408	None	5499	596	906	906	Aug 30, 2021 8:03 AM	Sep 9, 2021 5:26 AM
Mike's BOL	584BC8000202381	None	6685	717	1700	1700	Aug 30, 2021 7:40 AM	Sep 9, 2021 3:04 AM
TBHH100_5	584BC800011B46B	DatacakeIntegration CUS_RH	922	142	820	820	Aug 3, 2021 6:42 AM	Sep 8, 2021 7:13 PM
TBHH100_6	584BC800011C142	CUS_SF	809	144	662	662	Aug 9, 2021 6:31 AM	Sep 9, 2021 12:20 AM
TBHV110_5	584BC800011E3A2	CUS_RH	2261	322	6618	6618	Aug 8, 2021 10:52 AM	Sep 9, 2021 4:41 AM
TBHV110_6	584BC800011E1E1	CUS_SF	7928	163	4772	4772	Aug 12, 2021 4:29 PM	Sep 9, 2021 5:24 AM
TBWL100_5	E8E1E10001040ED9	CUS_RH	920	104	675	675	Aug 4, 2021 6:59 AM	Sep 8, 2021 3:51 PM
TBWL100_6	E8E1E10001040ED8	CUS_RH	795	103	651	651	Aug 4, 2021 7:00 AM	Sep 8, 2021 2:39 PM

Screenshot 1 – Frame Up and Packets Transferred information in the Helium Console

By recording the Frame Up and Packets Transferred information for each sensor every morning, a daily packet completion percentage can be calculated for each sensor. This works as long as the sensor’s frame count variable is not reset. If the frame count is reset between Frame Up readings, the daily packet completion percentage calculation will be invalid for that day. This doesn’t happen very often and is easily seen in the log, so that when the sensor’s frame count is reset during the measurement period, the performance measurement can be discarded or ignored.

The log file, *20210922\_Hotspot and DC Tracker - VIP.xlsx*, is where the daily Frame Up and Packets Transferred data is recorded for the sensors in the Rogers and Sunrise systems. The log file, *20210911\_Hotspot and DC Tracker.xlsx*, is where the daily Frame Up and Packets Transferred data is recorded for the sensors in the Longview system. These logs also calculate the daily system performance by summing the performance of the sensors in the system.

Screenshot 2 shows an excerpt from the log file, *Hotspot and DC Tracker - VIP.xlsx*. In the screenshot, pink columns BX-CF correspond to sensor TBHV110\_6. The first 4 columns for that sensor (BX - CA) are where data from the VIP Console is recorded. The last 4 columns for that sensor (CB - CF) are calculated from the present and previous day's values in columns BX - CA. The green columns at the end (CQ - CS and CU - CW) are calculated from sensor columns to the left and show the overall daily packet completion percent for the Rogers and Sunrise systems.

	A	BO	BP	BQ	BR	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF	CP	CQ	CR	CS	CT	CU	CV	CW	CX
1	Date	Frame Up (TBHV110_5)	Frame Down	Packets Xferred	DC Used	Frame Up Yest (Calc)	Frame Down Yest (Calc)	Packets Xferred Yest (Calc)	PC% (Calc)	DC UsedY est (Calc)	Frame Up (TBHV110_6)	Frame Down	Packets Xferred	DC Used	Frame Up Yest (Calc)	Frame Down Yest (Calc)	Packets Xferred Yest (Calc)	PC% (Calc)	DC UsedY est (Calc)	Rogers Total FC Yest	Rogers Total Pkts Xferred Yest	Rogers Total PC% Yest (Calc) =BV/BU (-BOL)	Sunrise Total FC Yest (-BOL)	Sunrise Total Pkts Xferred Yest (-BOL)	Sunrise Total PC% Yest (Calc) =CV/CW (-BOL)	Note		
16	8/16/2021	2238	34	2713	2713	196	3	219	112%	219	1021	16	1215	1215	196	3	227	116%	227	245	271	111%	213	244	115%			
17	8/17/2021	2526	38	3033	3033	288	4	320	111%	320	1309	21	1534	1534	288	5	319	111%	319	360	393	109%	313	344	110%	Carry Sensors to Rogers 6pm flight		
18	8/18/2021	2839	43	3240	3240	313	5	207	66%	207	1623	26	1727	1727	314	5	193	61%	193	371	241	65%	344	209	61%	hotspot wasn't fully online until afternoon		
19	8/19/2021	3114	48	3520	3520	275	5	280	102%	280	1897	30	2019	2019	274	4	292	107%	292	367	351	96%	297	315	106%			
20	8/20/2021	3456	53	3843	3843	322	5	323	100%	323	2219	35	2355	2355	322	5	336	104%	336	404	405	100%	348	362	104%			
21	8/21/2021	3697	57	4104	4104	261	4	261	100%	261	2480	39	2614	2614	261	4	259	99%	259	327	327	100%	286	284	99%	Steve flew home with BOL_4, TBHV100_6 and TBHV110		
22	8/22/2021	4037	62	4443	4443	340	5	339	100%	339	2821	45	2777	2777	341	6	163	48%	163	432	431	100%	369	175	47%			
23	8/23/2021	4272	67	4681	4681	235	5	238	101%	238	3055	48	3008	3008	234	3	231	99%	231	309	312	101%	254	251	99%			
24	8/24/2021	4575	71	4989	4989	303	4	308	102%	308	3358	54	3302	3302	303	6	294	97%	294	384	388	101%	343	334	97%			
25	8/25/2021	4844	76	5264	5264	269	5	275	102%	275	3627	58	3568	3568	269	4	266	99%	266	337	341	101%	293	290	99%			
26	8/26/2021	5127	82	5560	5560	283	6	296	105%	296	3910	62	3850	3850	283	4	282	100%	282	374	385	103%	307	306	100%			
27	8/27/2021	5460	88	5905	5905	333	101	345	104%	345	4242	163	4088	4088	332	101	238	72%	238	417	419	103%	365	271	74%	tbhv110_6 perf is down, wait and see if this is an abt		
28	8/28/2021	5741	183	5974	5974	281	0	69	25%	69	4524	163	4130	4130	282	0	42	15%	42	357	142	40%	305	64	21%	performance is degraded for tbhv110_5 as well as tb		
29	8/29/2021	6007	183	6039	6039	266	0	65	24%	65	4791	163	4176	4176	267	0	46	17%	46	343	142	41%	289	68	24%	performance remains degraded for tbhv110 devices		
30	8/30/2021	6288	183	6117	6117	281	0	78	28%	78	5070	163	4229	4229	279	0	53	19%	53	365	161	44%	305	79	26%			
31	8/31/2021	6583	183	6190	6190	295	0	73	25%	73	5368	163	4284	4284	298	0	55	18%	55	372	149	40%	324	81	25%			
32	9/1/2021	6863	183	6257	6257	280	0	67	24%	67	5654	163	4328	4328	286	0	44	15%	44	355	119	34%	310	68	22%	TBWL100_5 perf has degraded for the 1st time		
33	9/2/2021	267	37	6296	6296	-6596	-146	39	-1%	39	5932	163	4387	4387	278	0	59	21%	59	-6526	91	-1%	305	86	28%	reset/rejoined tbhv110_5 at 7:18am shortly after recording stat		
34	9/3/2021	583	90	6349	6349	316	53	53	17%	53	6243	163	4451	4451	311	0	64	21%	64	409	97	24%	336	88	26%			
35	9/4/2021	813	130	6389	6389	230	40	40	17%	40	6478	163	4494	4494	235	0	43	18%	43	289	47	16%	255	49	19%			
36	9/5/2021	813	130	6389	6389	0	0	0	#####	0	6478	163	4494	4494	0	0	0	#####	0	0	0	#####	0	0	#####			
37	9/6/2021	1483	226	6513	6513	670	96	124	19%	124	7139	163	4626	4626	661	0	132	20%	132	651	152	18%	730	150	21%			
38	9/7/2021	1709	255	6543	6543	226	29	30	13%	30	7378	163	4666	4666	239	0	40	17%	40	298	39	13%	261	44	17%	Enable multi-packet for TBWL100_5		
39	9/8/2021	1965	287	6579	6579	256	32	36	14%	36	7638	163	4712	4712	260	0	46	18%	46	314	45	14%	283	53	19%			
40	9/9/2021	2261	322	6618	6618	296	35	39	13%	39	7928	163	4772	4772	290	0	60	21%	60	358	53	15%	309	66	21%			

Screenshot 2 – from 20210922\_Hotspot and DC Tracker - VIP.xlsx

Looking closely at the logs, one may notice that sometimes the PC% is greater than 100 (e.g. row 16 in Screenshot 2). This occurs when the number of Packets Transferred in the previous day is greater than the number of Frame Ups in the previous day. This is due to an ambiguity in how the Helium Console reports the Packets Transferred data. This has been reported to the Helium engineering team but no clear answer has been provided. What is known is that this phenomenon is **not** due to Multi-Packet setting nor is it obviously due to inclusion of the Frame Down messages.

Performance metrics for the Longview system is based on the data in columns GK-GM in the Devices tab of 20210911\_Hotspot and DC Tracker.xlsx.

Performance metrics for the Rogers and Sunrise systems is based on the data in columns CQ-CS and CU-CW in the Devices tab of 20210922\_Hotspot and DC Tracker - VIP.xlsx.

## Appendix B – System and Individual Sensor Performance Graphs for the Longview System

Chart B1 shows the aggregate packet completion rate over time for the sensors in the Longview system. The chart shows that the aggregate performance degraded over time. The system was built at Hitechdb and went online on 5/10/21 and was deployed to the customer site on 5/24/21

From 5/10 – 6/1 the PC rate was near 100%, except for 1 week where the Helium Network was having trouble. From 6/3 – 6/26, the PC rate was around 25%. Then from 6/26 onward, the PC% hovered around 14%.

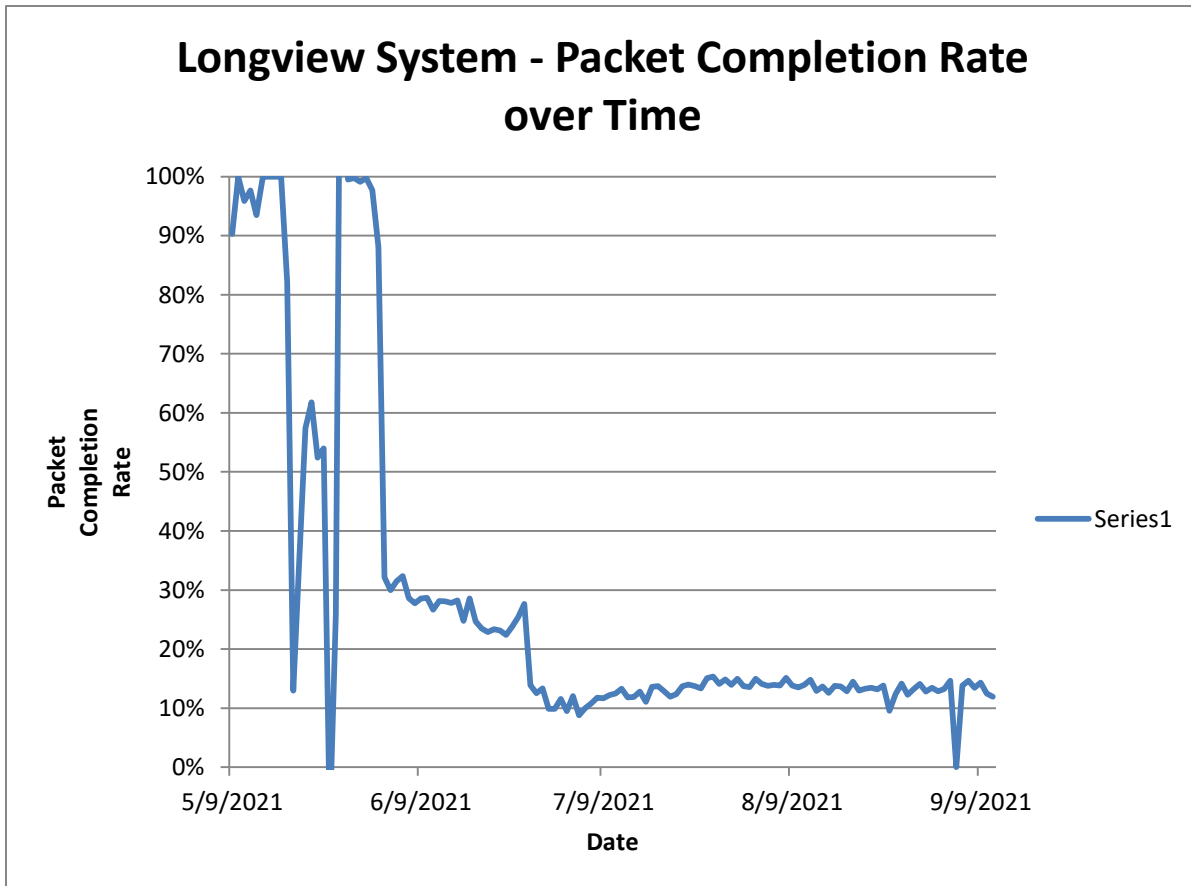


Chart B1 – Longview Packet Completion Rate over time  
(Chart taken from the 'Longview Performance' tab in 20210911\_Hotspot and DC Tracker.xlsx)

The remaining charts in this appendix look at individual sensor performance for each sensor in the Longview system. For each sensor, 2 different charts are provided. The data source for each chart is listed below.

- Packet Completion Rate over time
  - 20210911\_Hotspot and DC Tracker.xlsx
- RSSI/SNR over time
  - 20210908\_Log\_TBHH100.xlsx
  - 20210916\_TBHV110-fromHelium.xlsx
  - 20210912\_Log\_TBWL100.xlsx

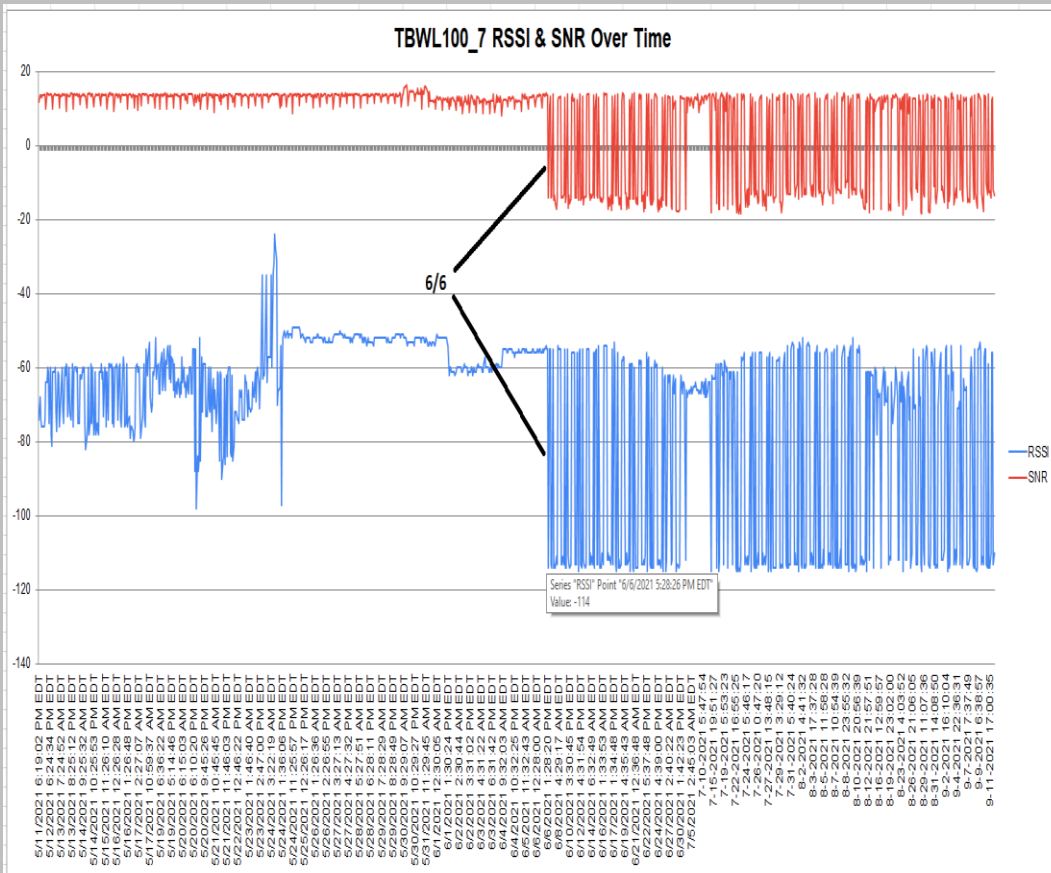
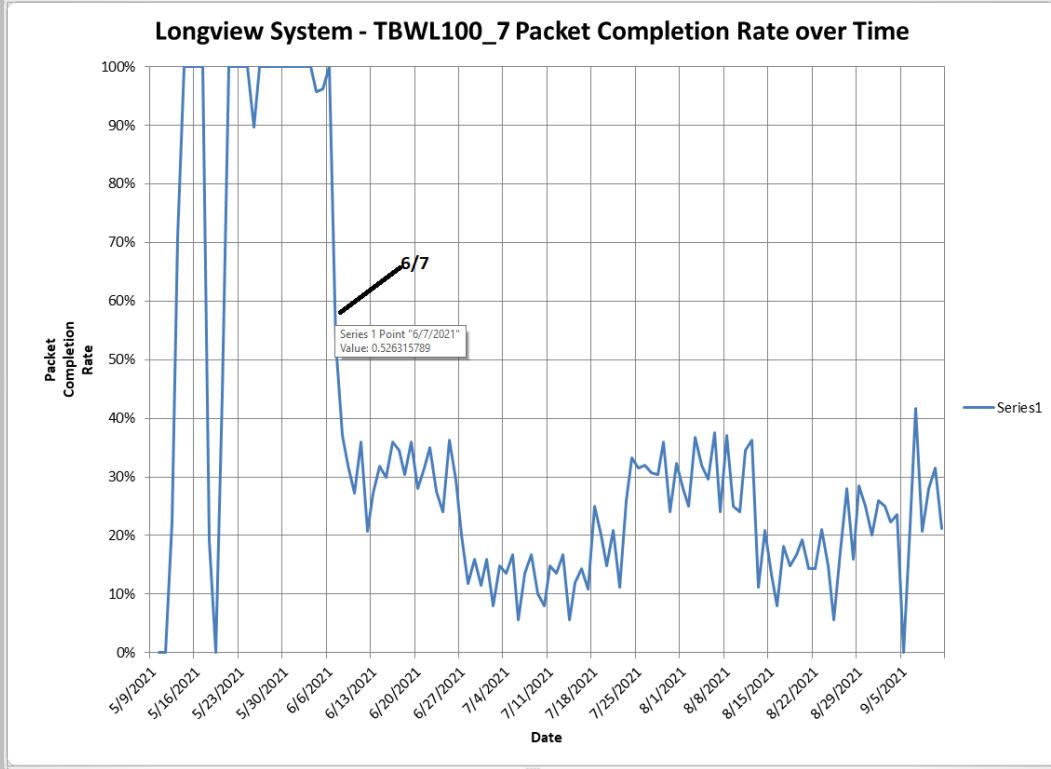
Oct. 11, 2021

The RSSI/SNR data is the sensor signal strength read by the IoT gateway that received the sensor message. For sensor data that was not received by the gateway – i.e. lost data, there is no RSSI/SNR information.

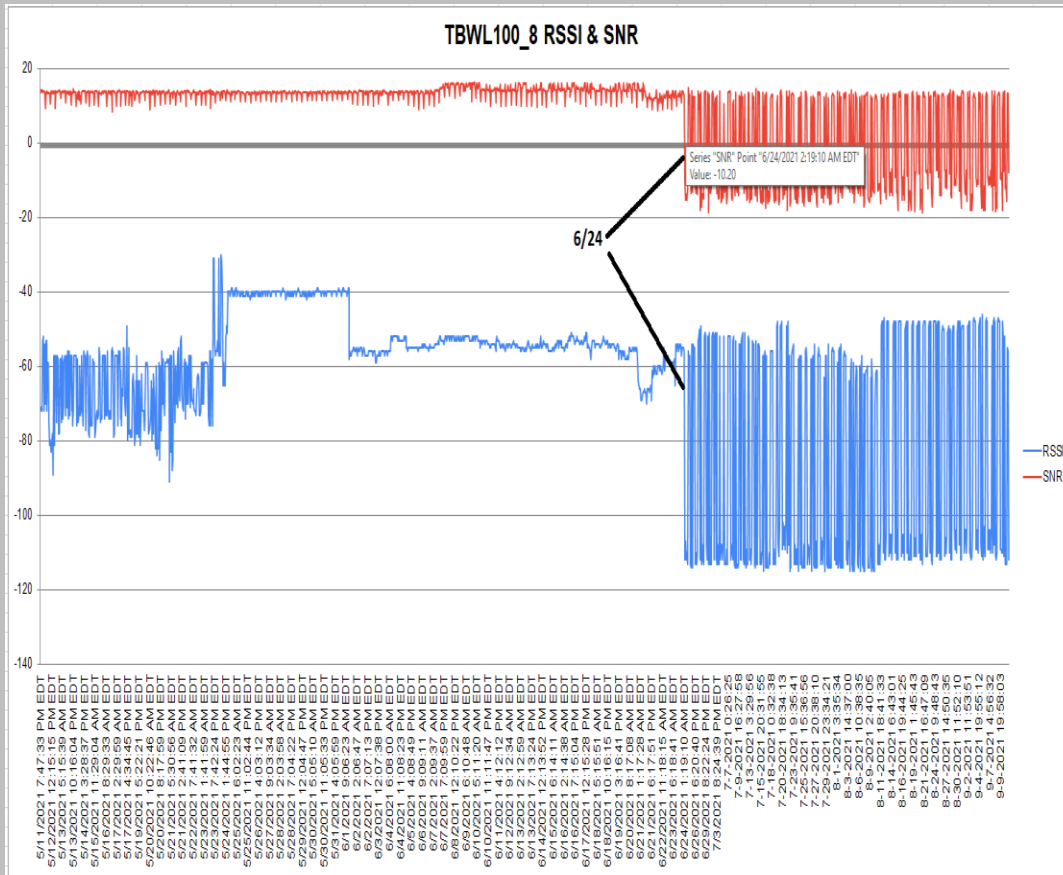
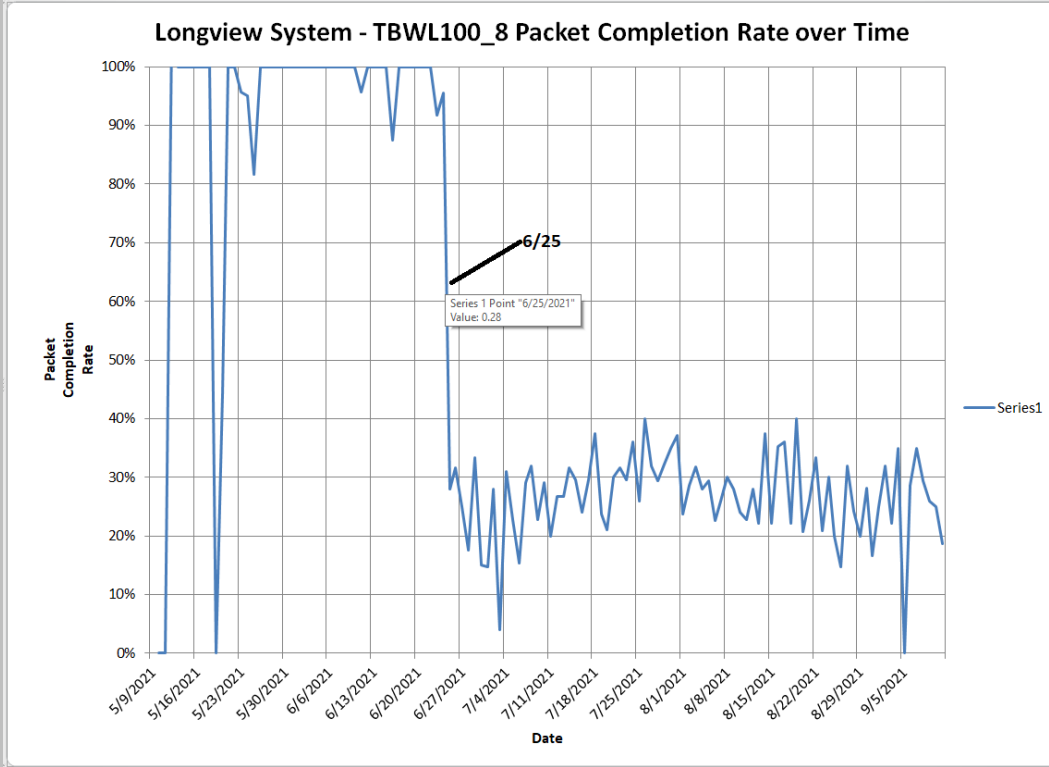
By comparing the 2 charts, one can see if there is a correlation between packet completion rate and signal strength.

Note that because spreading factor was not being captured in the sensor logs for the Longview system during this time, there is not Spreading Factor analysis for the Longview System.

Sensor TBWL100\_7

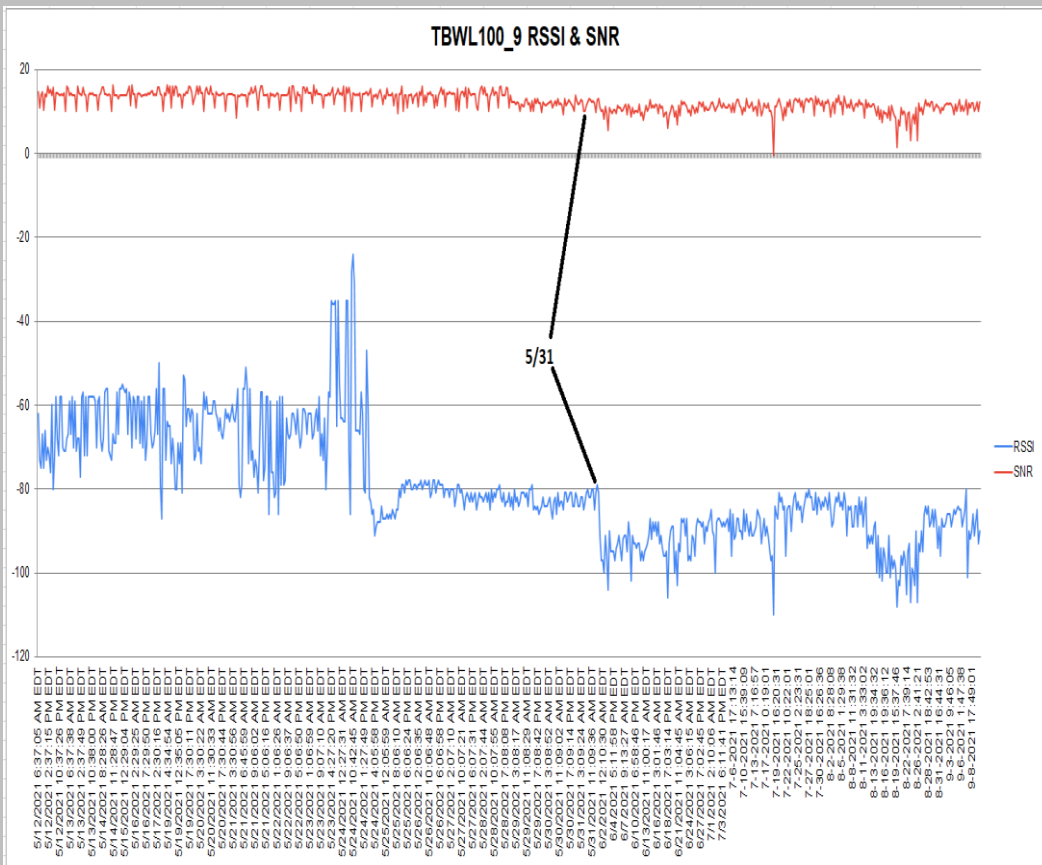
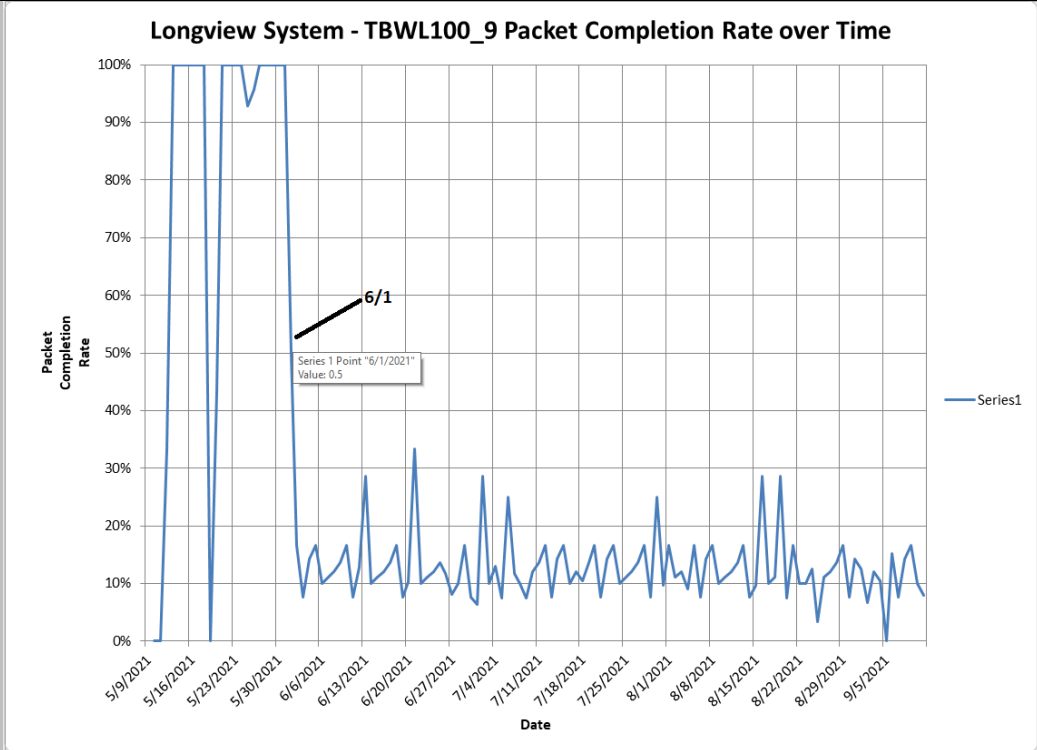


Sensor TBWL100\_8

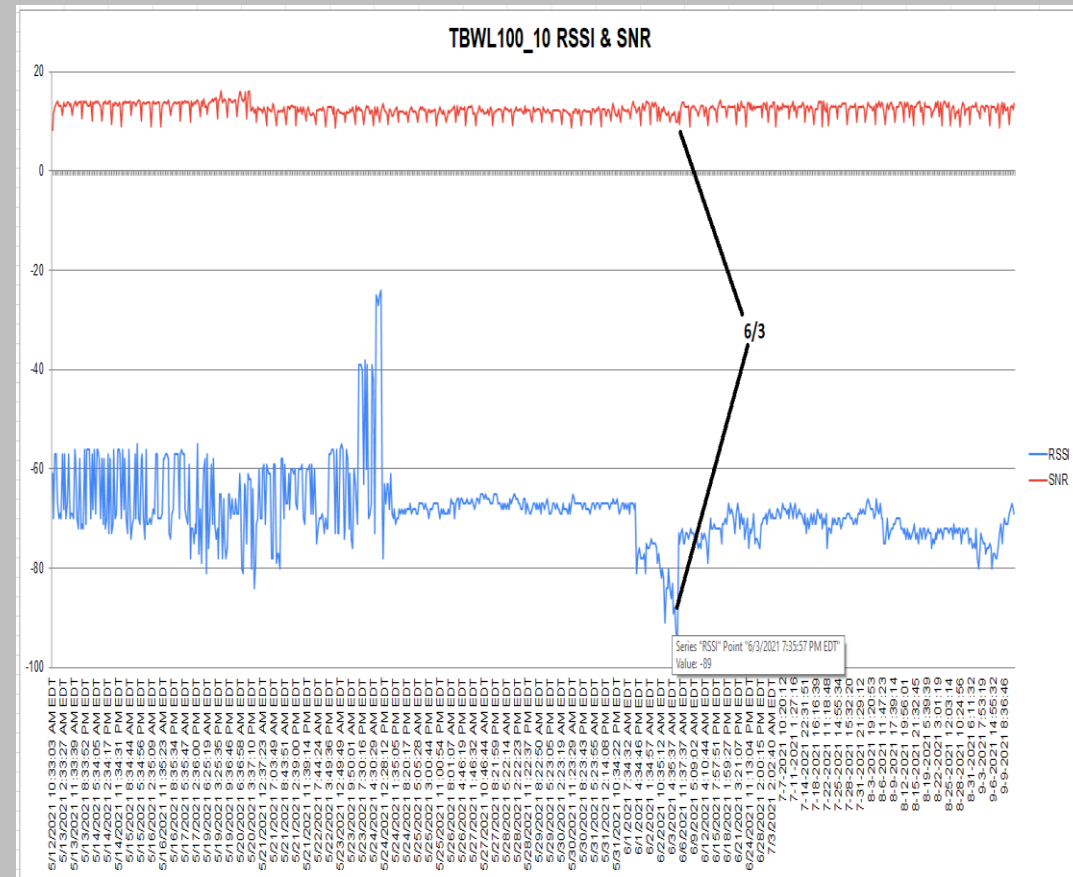
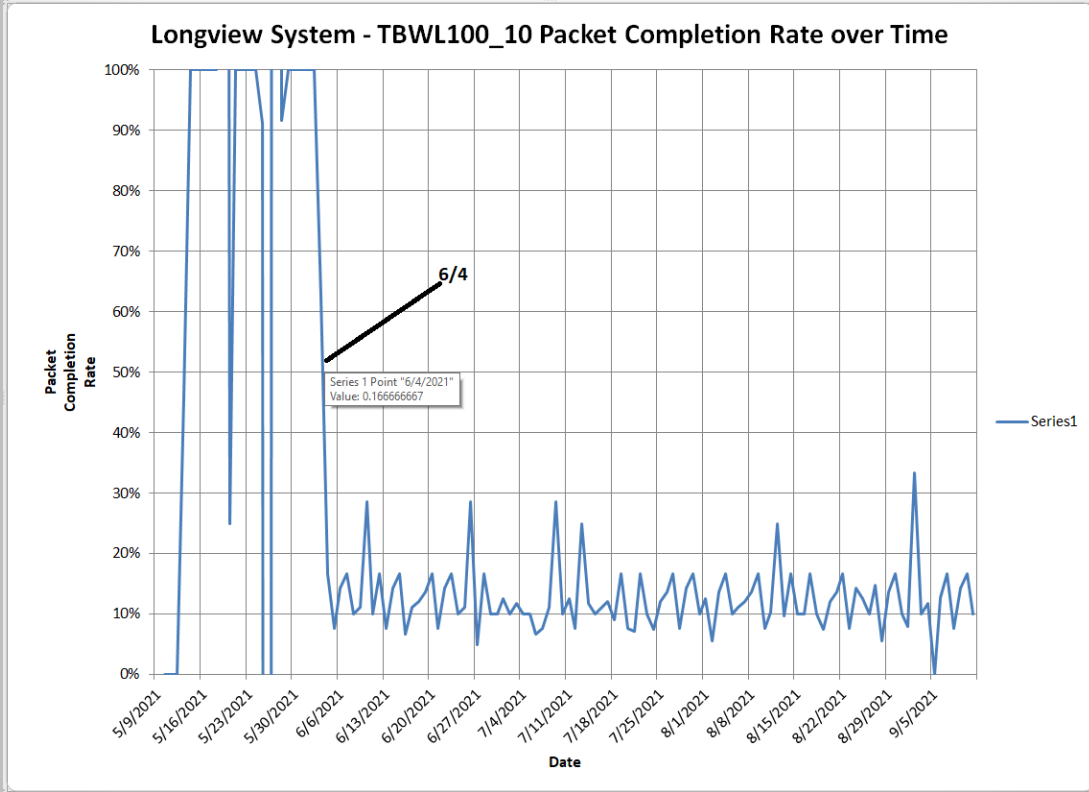




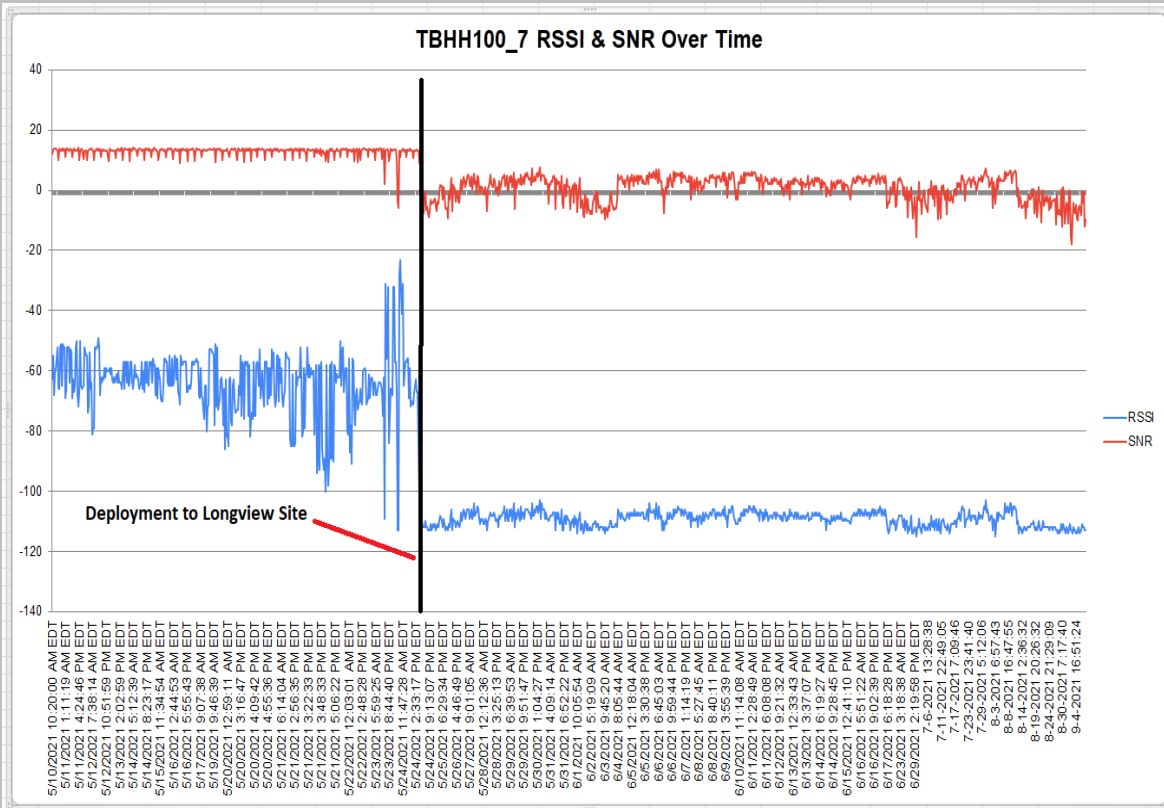
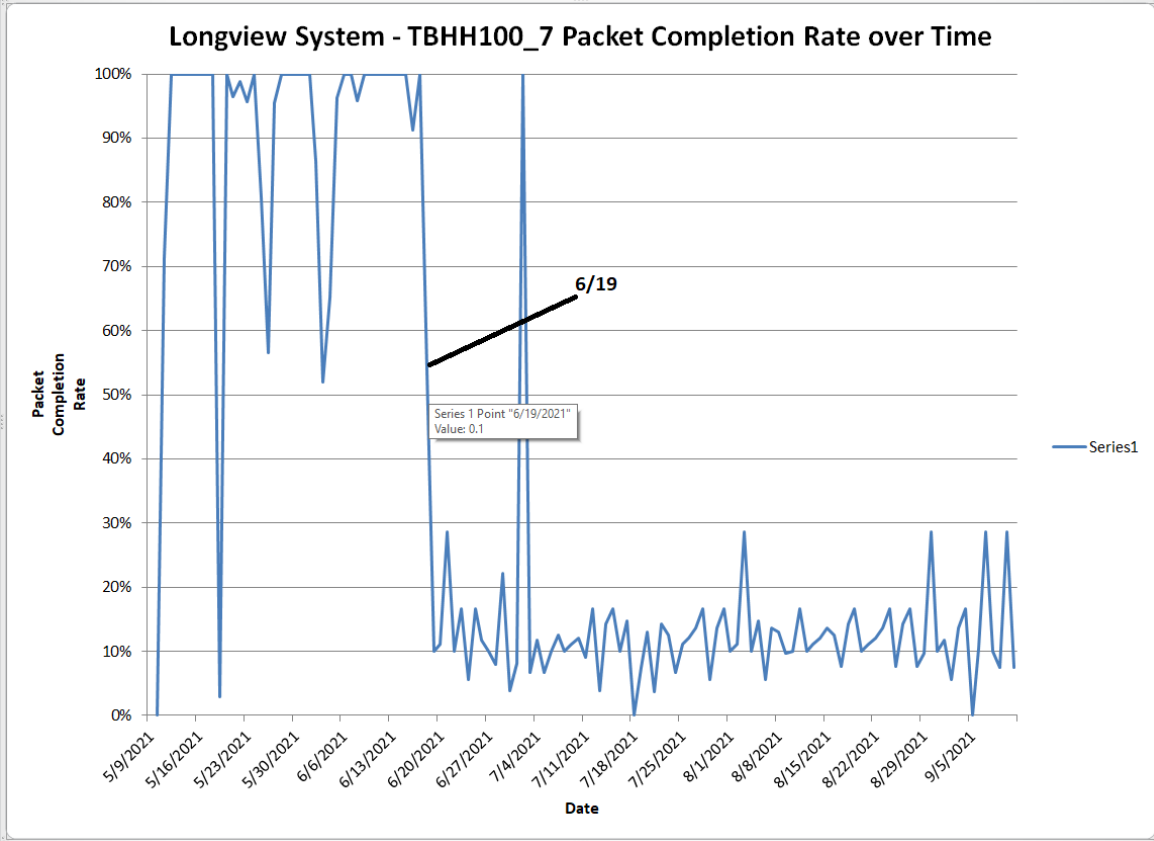
Sensor TBWL100\_9



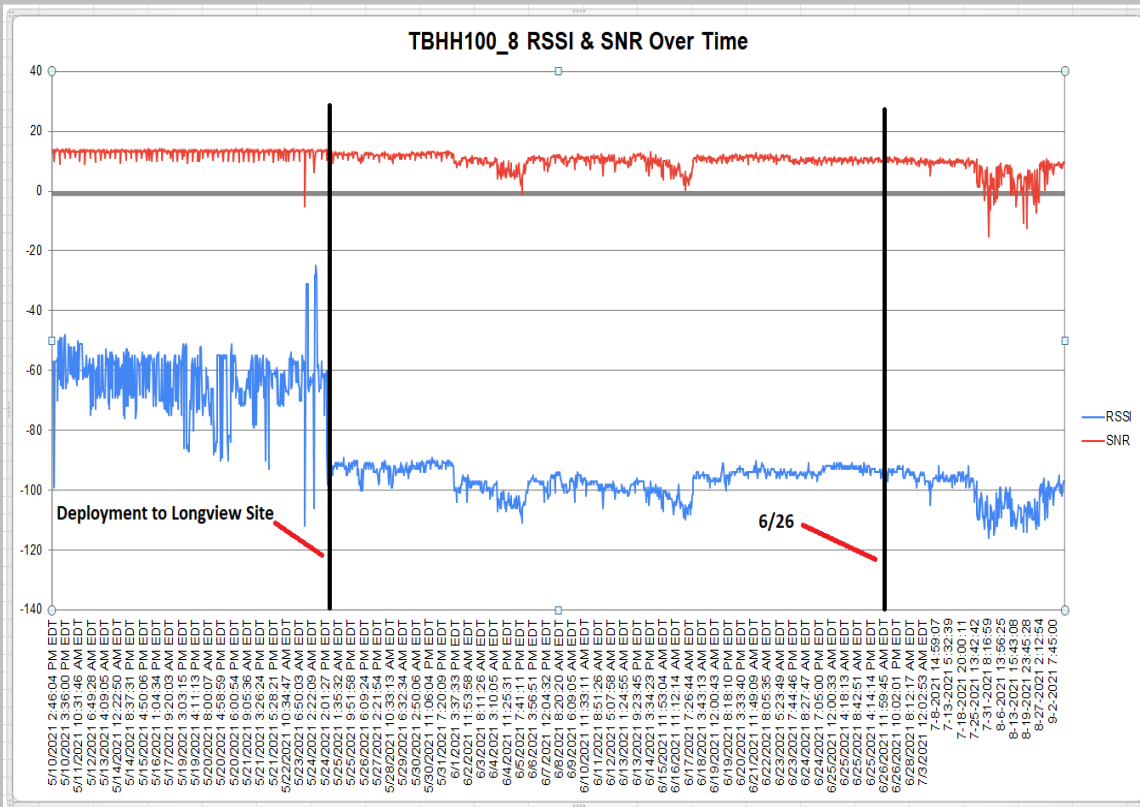
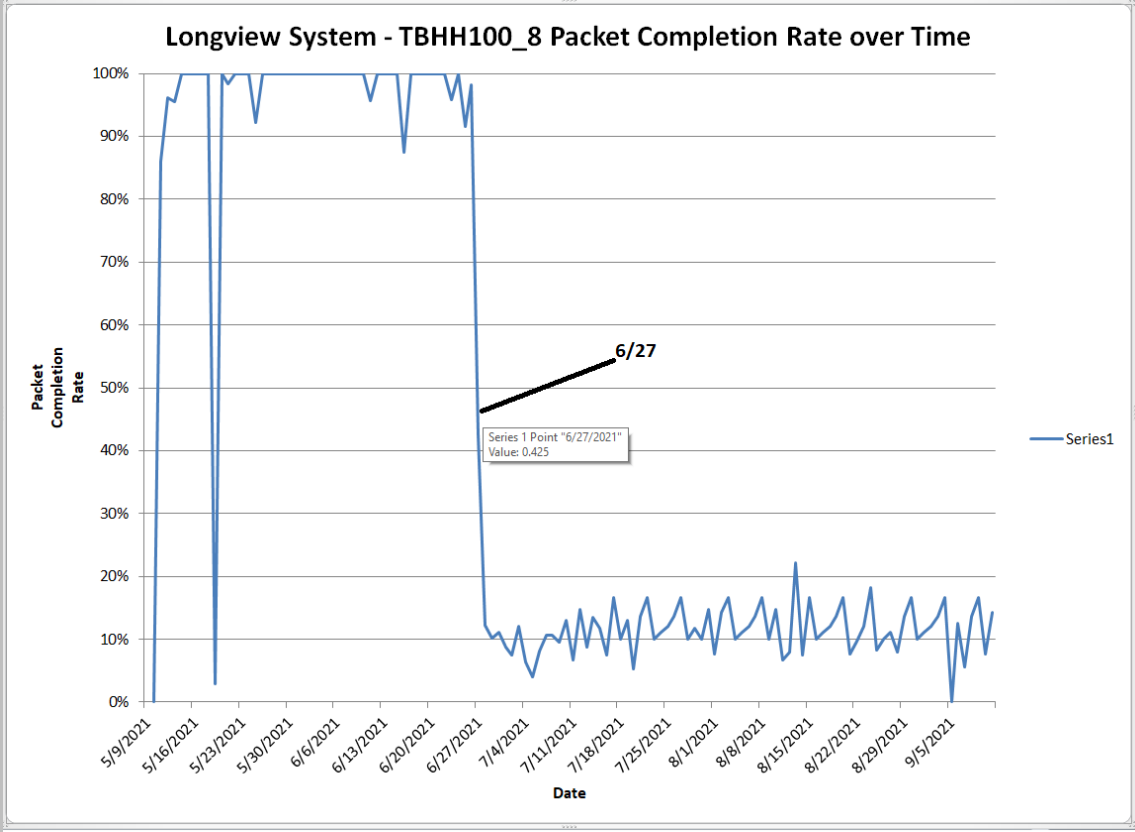
Sensor TBWL100\_10



TBHH100\_7

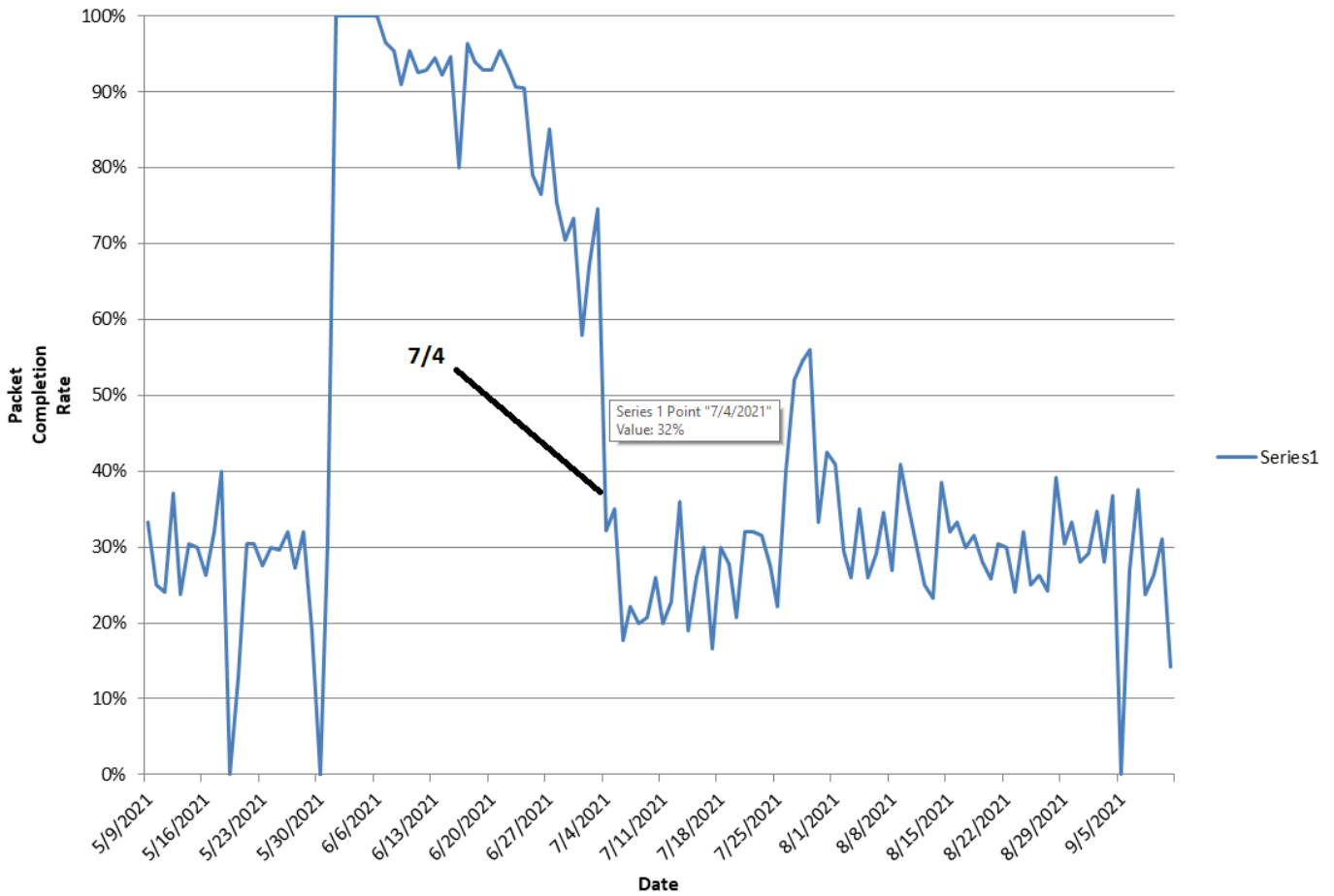


TBHH100\_8

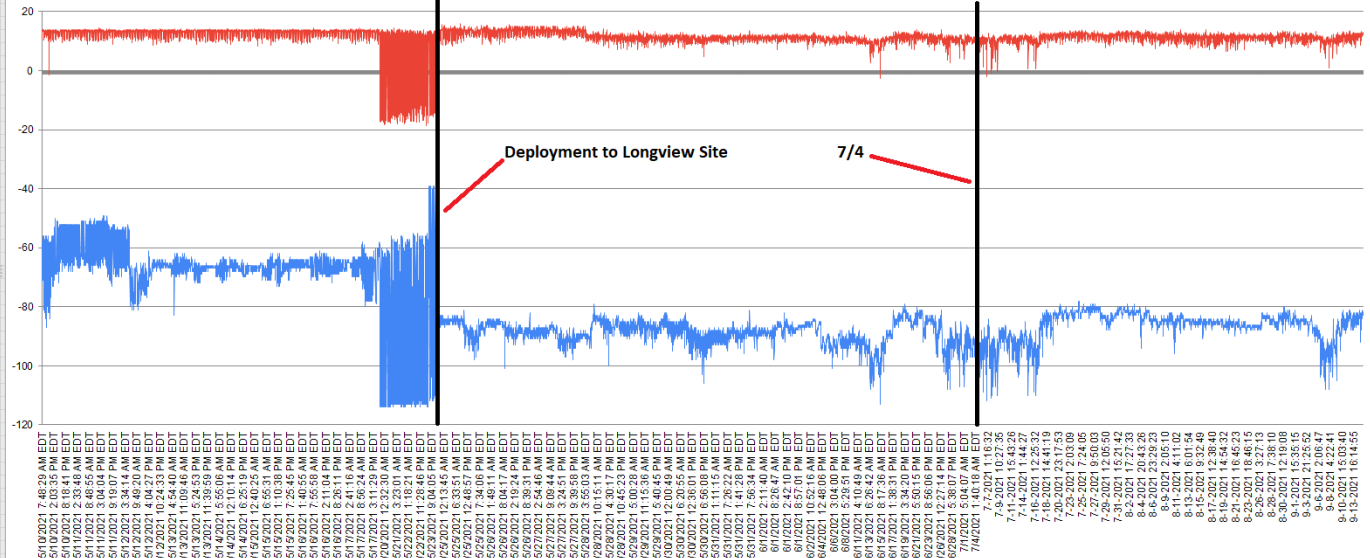


TBHV110\_4

Longview System - TBHV110\_4 Packet Completion Rate over Time



TBHV110\_4 RSSI & SNR Over Time



## Appendix C – System and Individual Sensor Performance Graphs for the Sunrise System

Chart C1 shows the aggregate packet completion rate over time for the sensors in the Sunrise system. The chart shows that the aggregate performance degrades over time. The system was built at Hitechdb and went online on 8/9/21 and was deployed to the customer site on 8/21/21

From 8/9 – 8/26 the PC rate was near 100%, except for 8/18 and 8/22. The performance decline on 8/18 and 8/22 was due to the sensors being in transit on 8/17 and then again on 8/21. Between 8/27 and 8/28 the PC rate went on a sharp decline after which it steadied out around 14%. Starting on 8/22, the sensors are connecting to the Helium network via a single hotspot, best-pearl-aardvark, which is located at the Sunrise site.

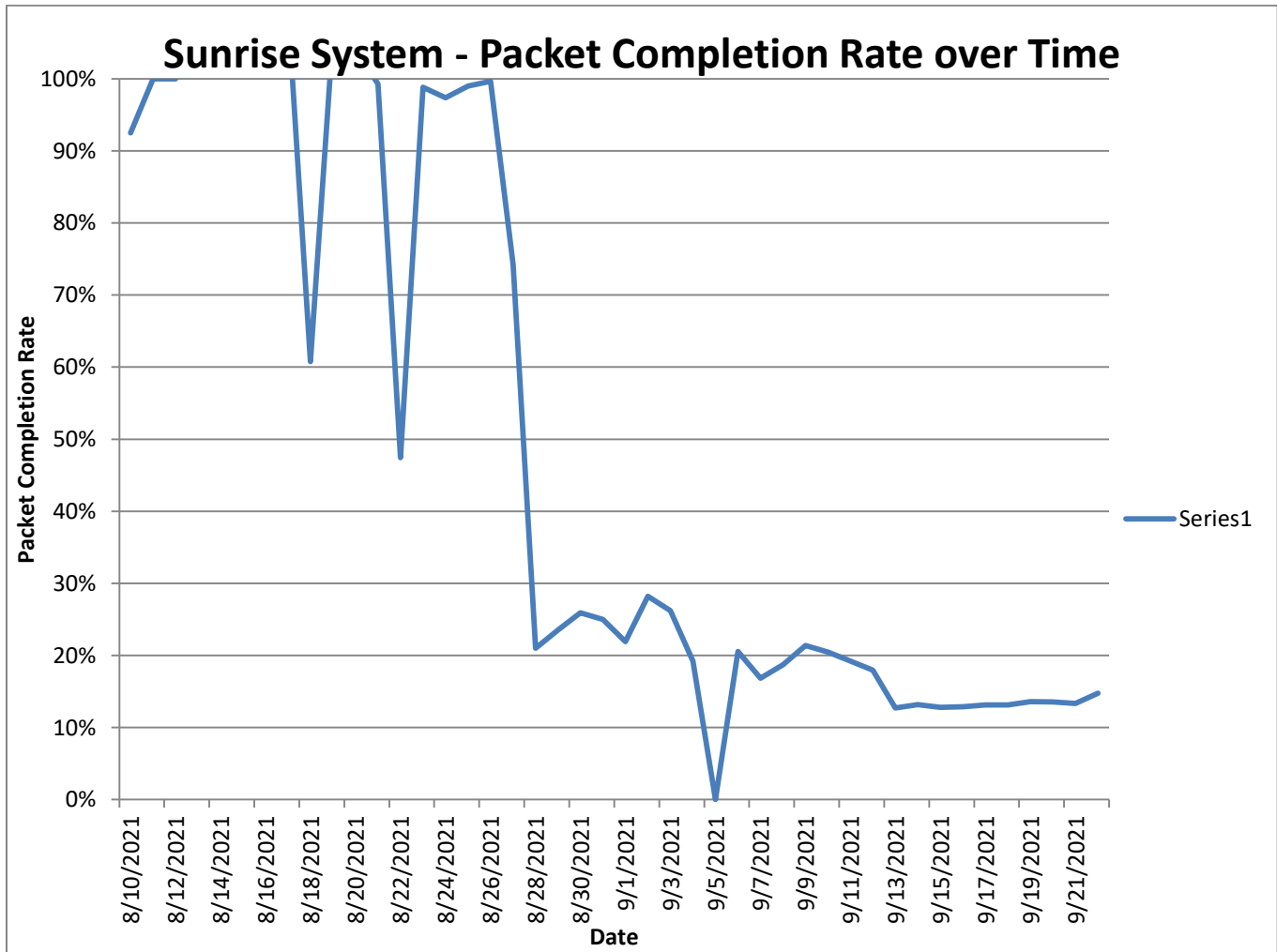


Chart C1 – Sunrise Packet Completion Rate over time  
 (Chart taken from the ‘Sunrise System Performance’ tab in 20210922\_Hotspot and DC Tracker - VIP.xlsx)

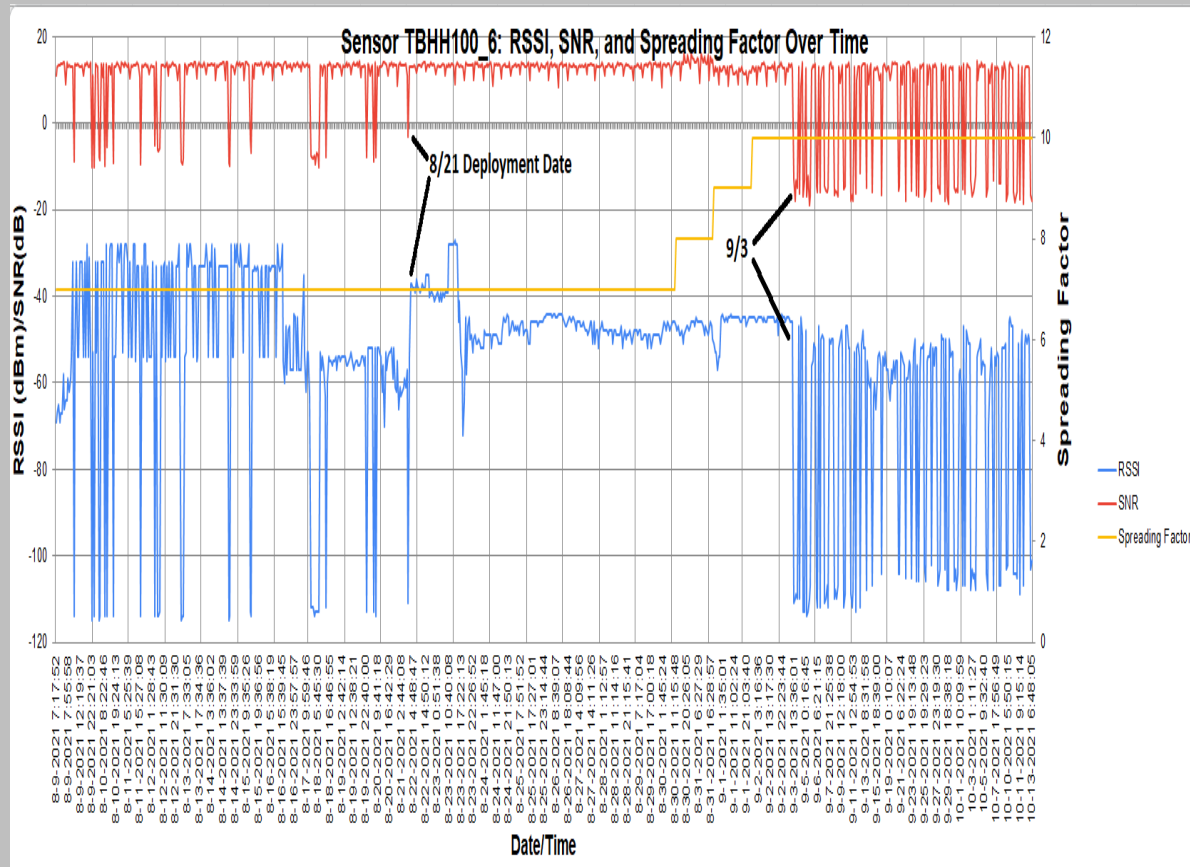
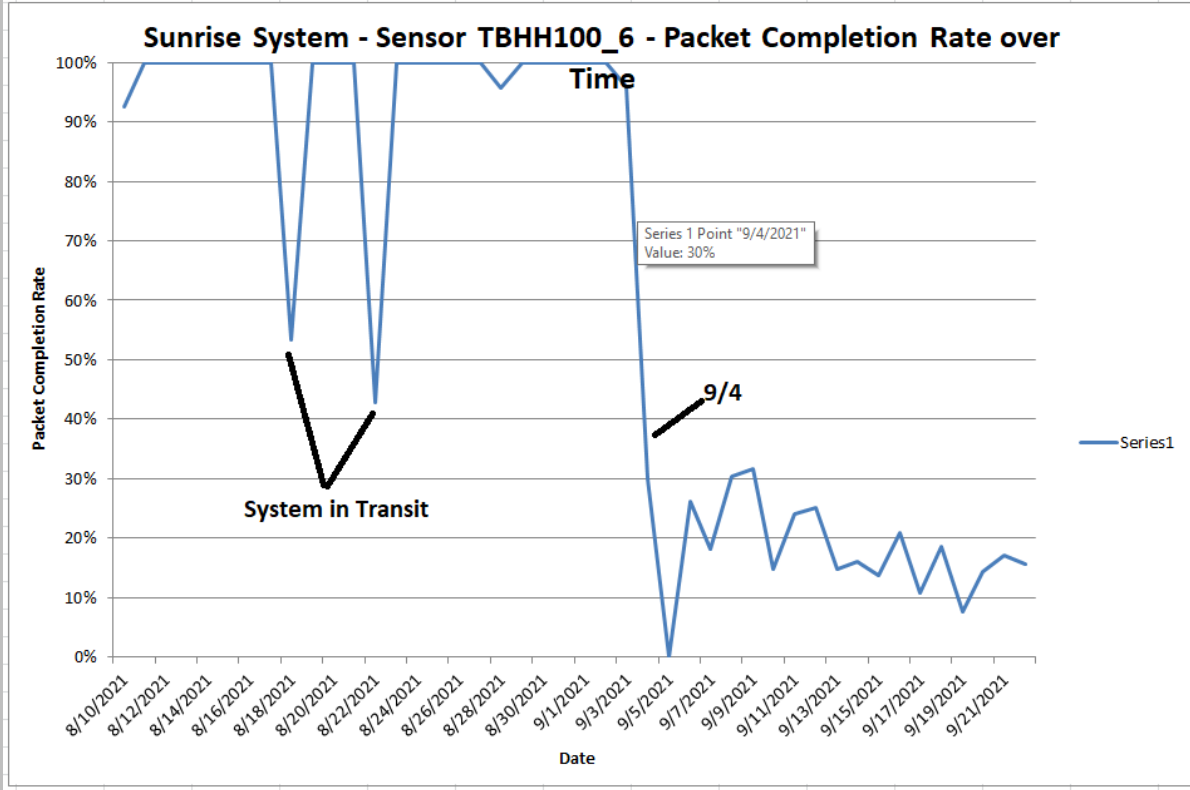
The remaining charts in this appendix look at individual sensor performance for the sensors in the Sunrise system. For each sensor, 2 different charts are provided. The data source for each chart is listed below.

- Packet Completion Rate over time
  - 20210922\_Hotspot and DC Tracker - VIP.xlsx

- RSSI/SNR/Spreading Factor over time
  - *20211013\_Log\_SunriseFamilyFarm\_SensorDataFlow.xlsx*

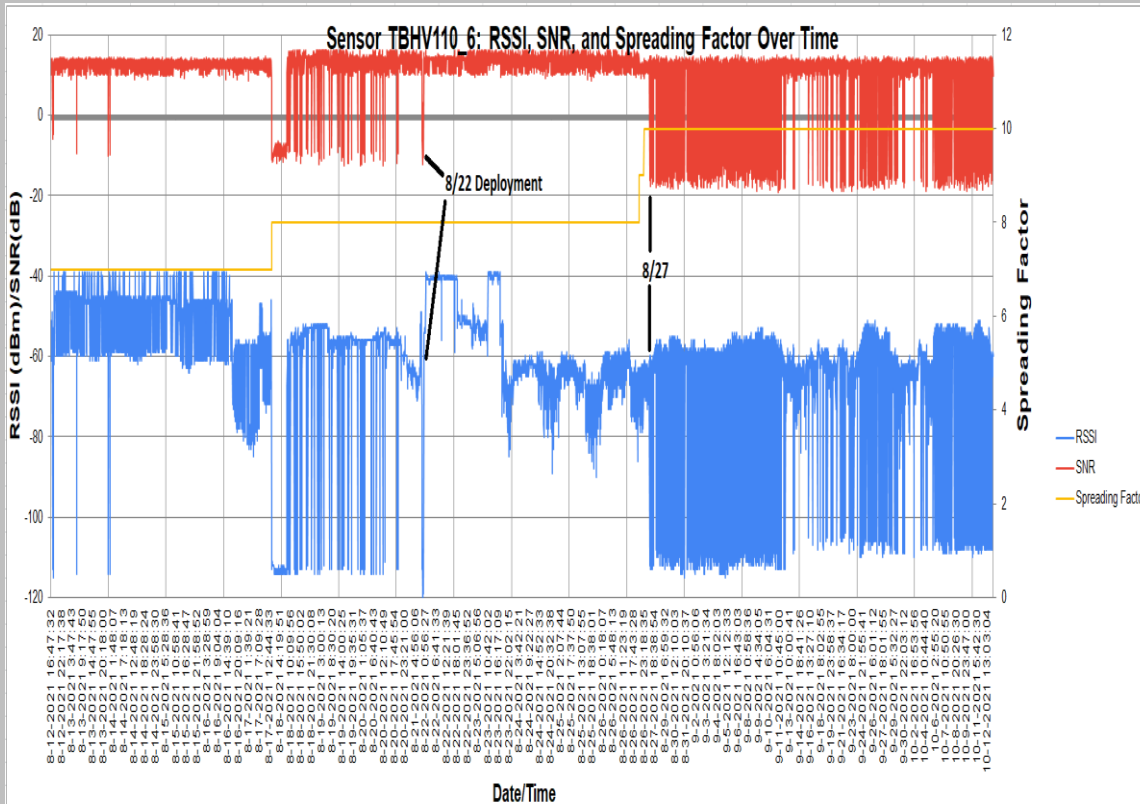
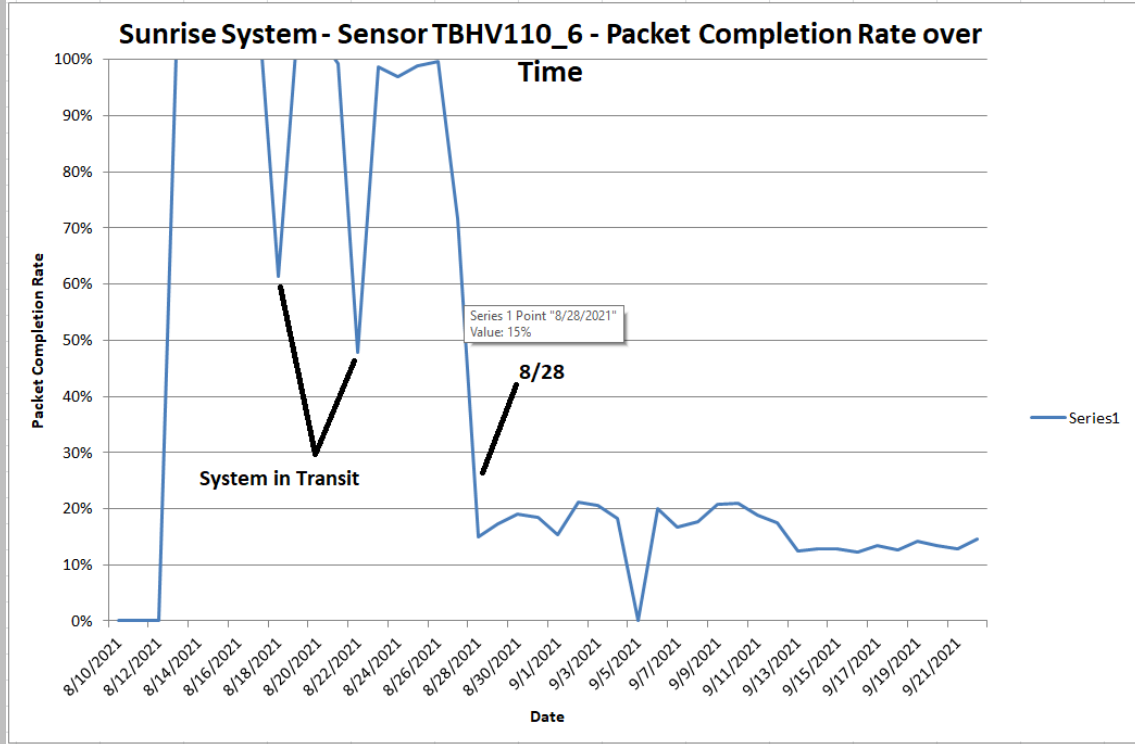
The RSSI/SNR/SF data is read by the IoT gateway that received the sensor message. For sensor data that was not received by the gateway – i.e. lost data, there is no RSSI/SNR/SF information.

Sensor TBHH100\_6





Sensor TBHV110\_6



## Appendix D – System and Individual Sensor Performance Graphs for the Rogers System

Chart D1 shows the aggregate packet completion rate over time for the sensors in the Rogers system. The chart shows that the aggregate performance degrades over time. The system was built at Hitechdb and went online on 8/5/21 and was deployed to the customer site on 8/17 and 8/18/21

From 8/4 – 8/28 the PC rate was near 100%, except for 8/6 and 8/18. Then on 8/28 the PC rate went on a sharp decline after which it steadied out around 14%.

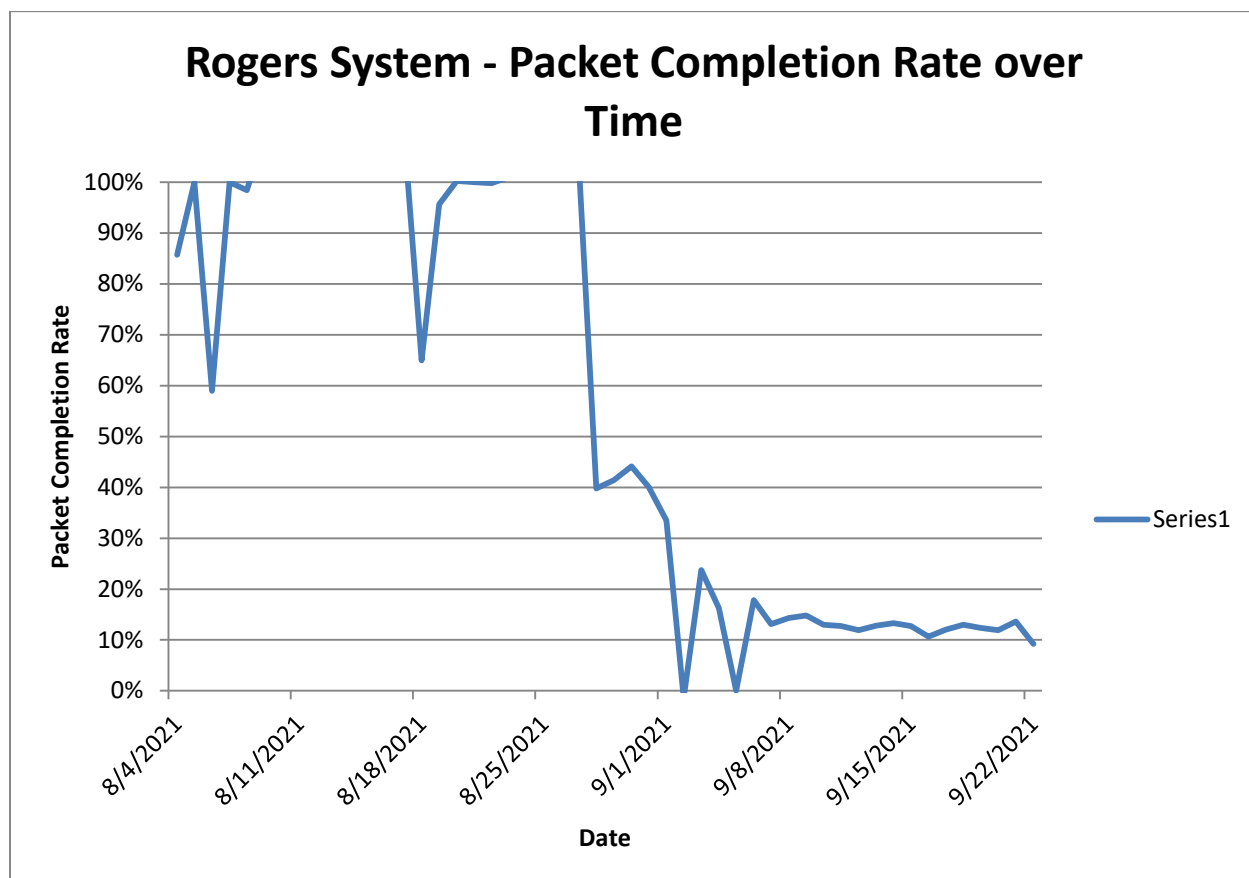


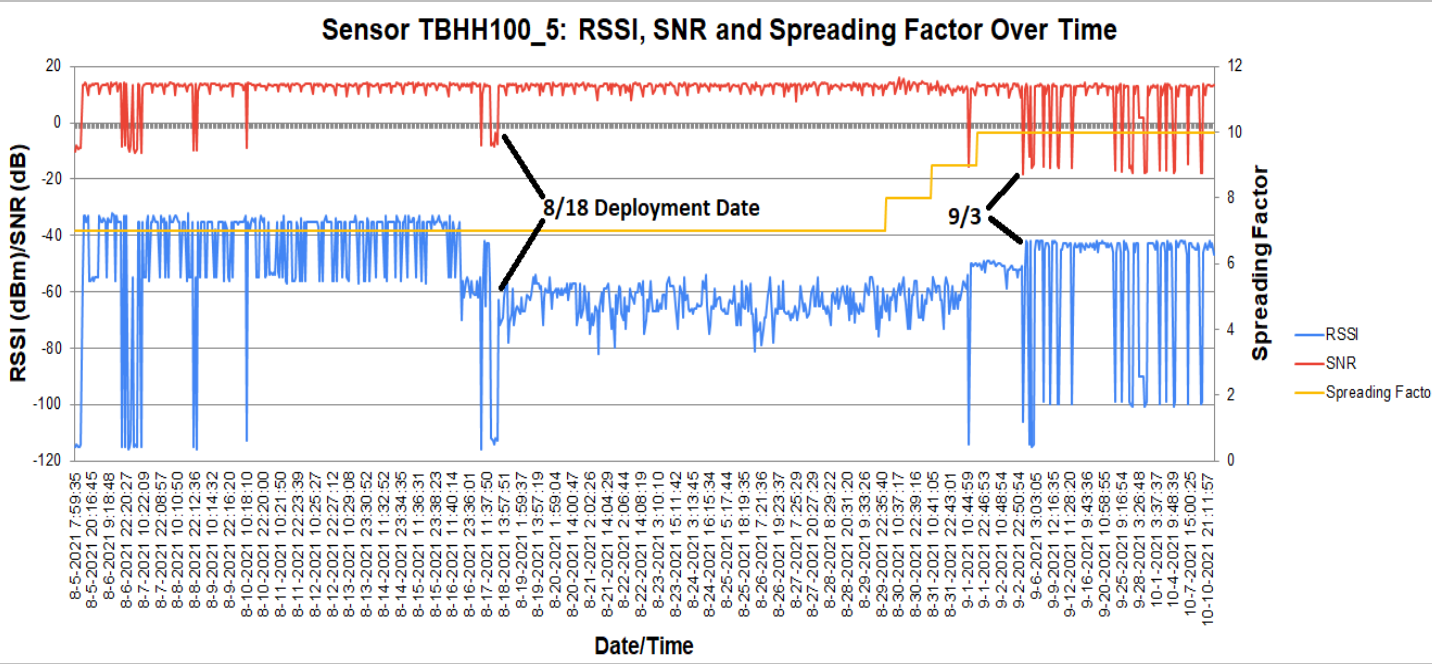
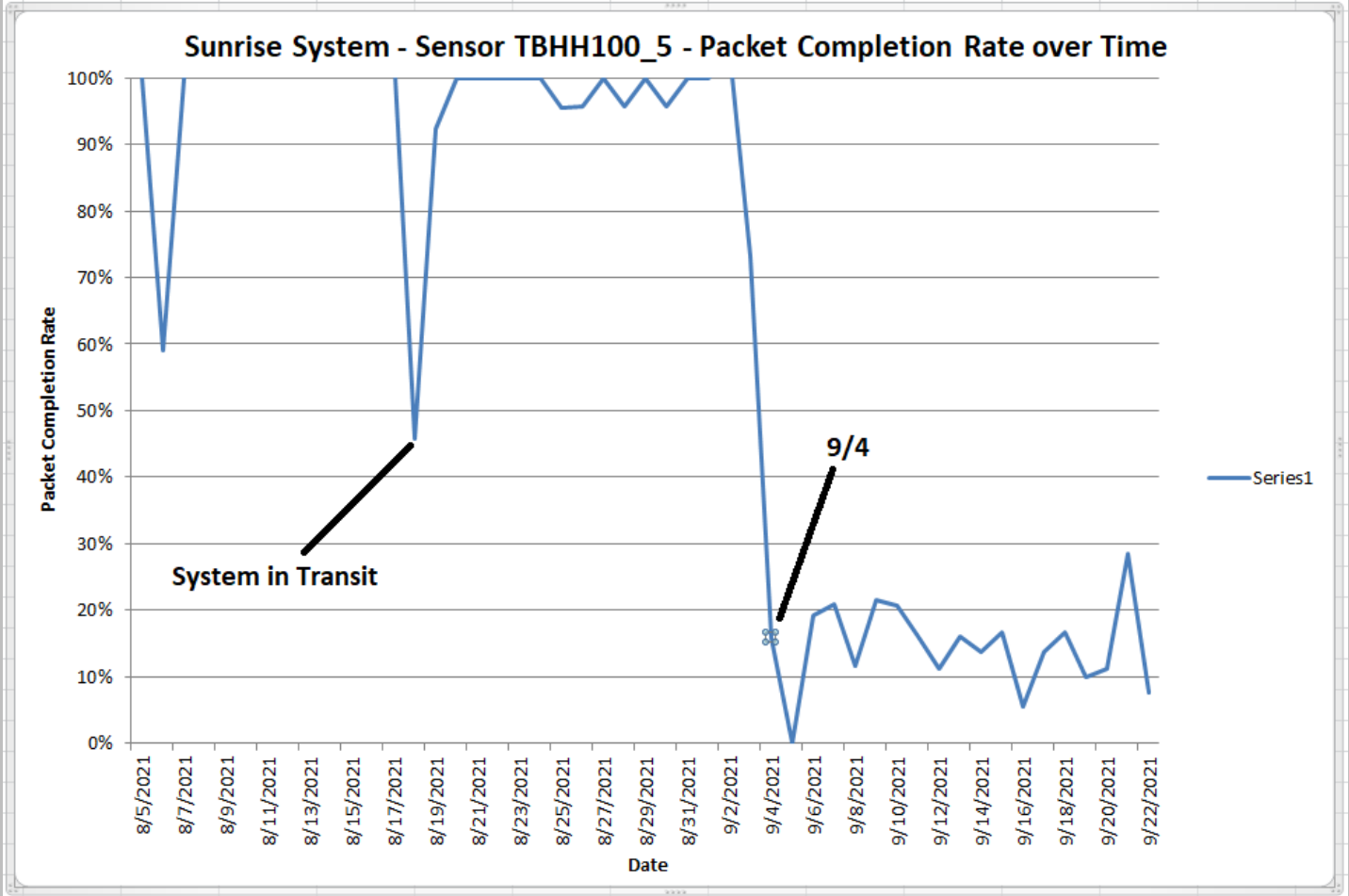
Chart D1 – Rogers Packet Completion Rate over time  
 (Chart taken from the ‘Rogers System Performance’ tab in 20210922\_Hotspot and DC Tracker - VIP.xlsx)

The remaining charts in this appendix look at individual sensor performance for the sensors in the Rogers system. For each sensor, 2 different charts are provided. The data source for each chart is listed below.

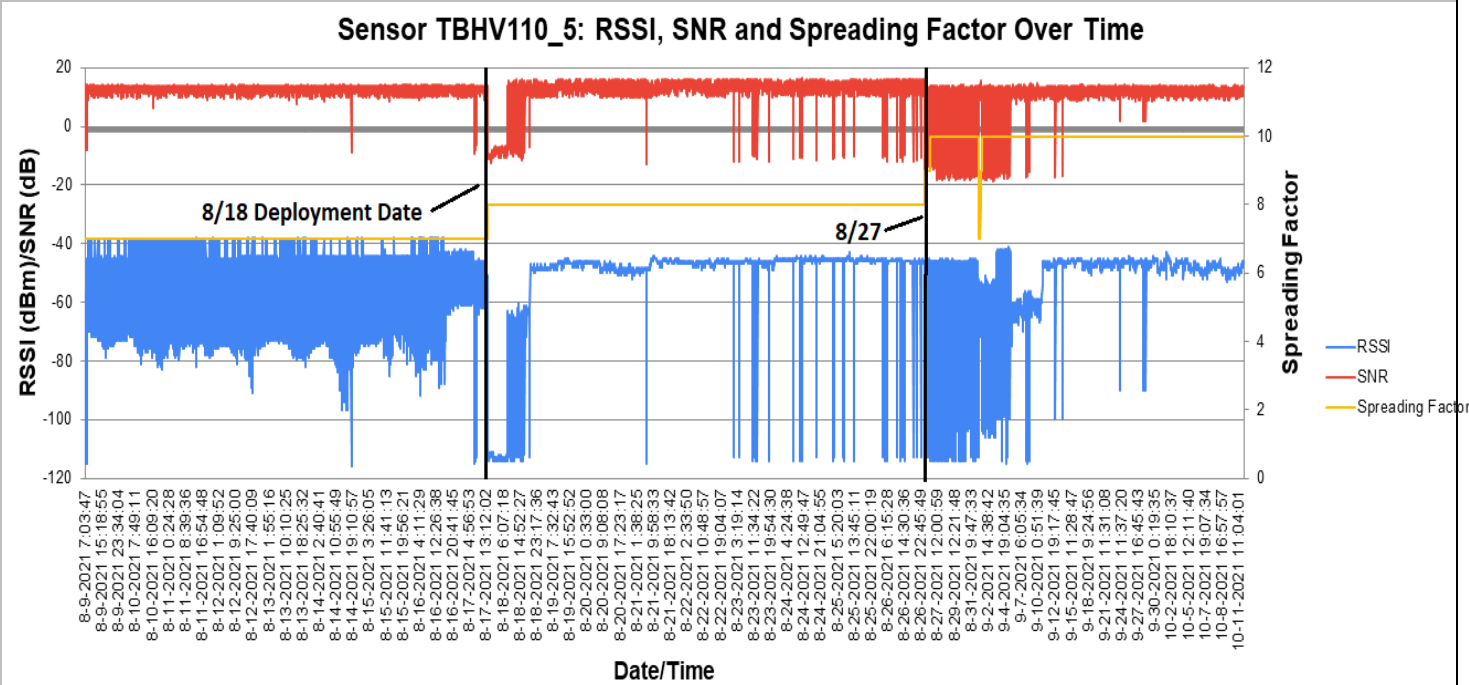
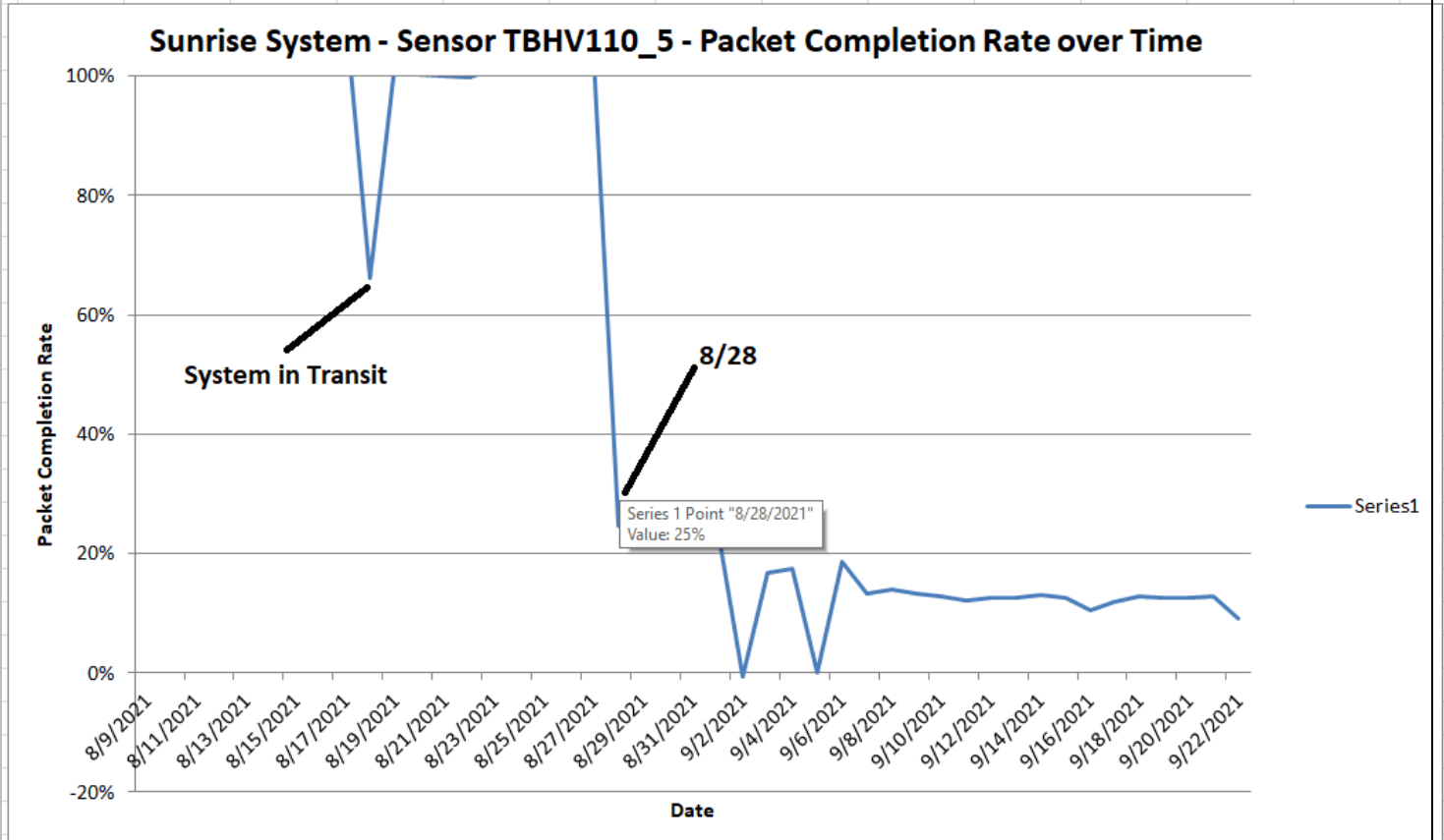
- Packet Completion Rate over time
  - 20210922\_Hotspot and DC Tracker - VIP.xlsx
- RSSI/SNR/Spreading Factor over time
  - 20211012\_Log\_RogersHome\_SensorDataFlow.xlsx

The RSSI/SNR/SF data is read by the IoT gateway that received the sensor message. For sensor data that was not received by the gateway – i.e. lost data, there is no RSSI/SNR/SF information.

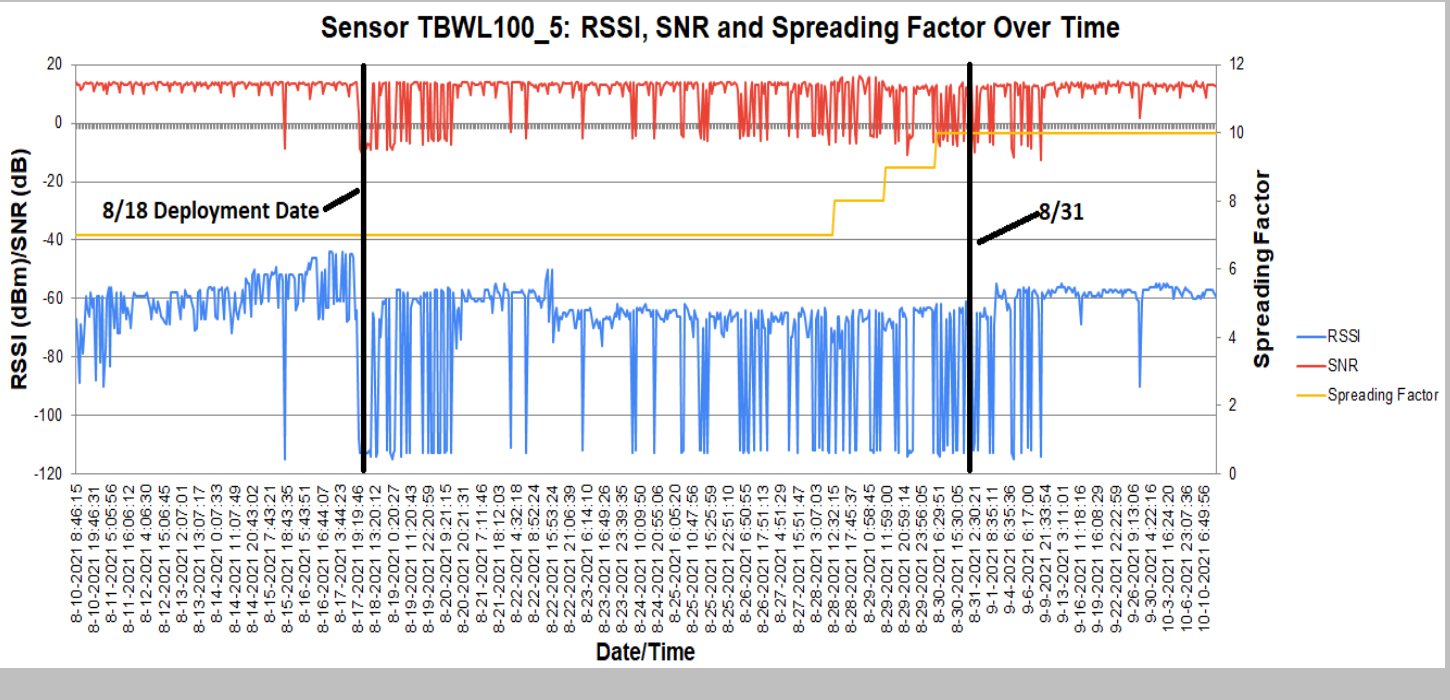
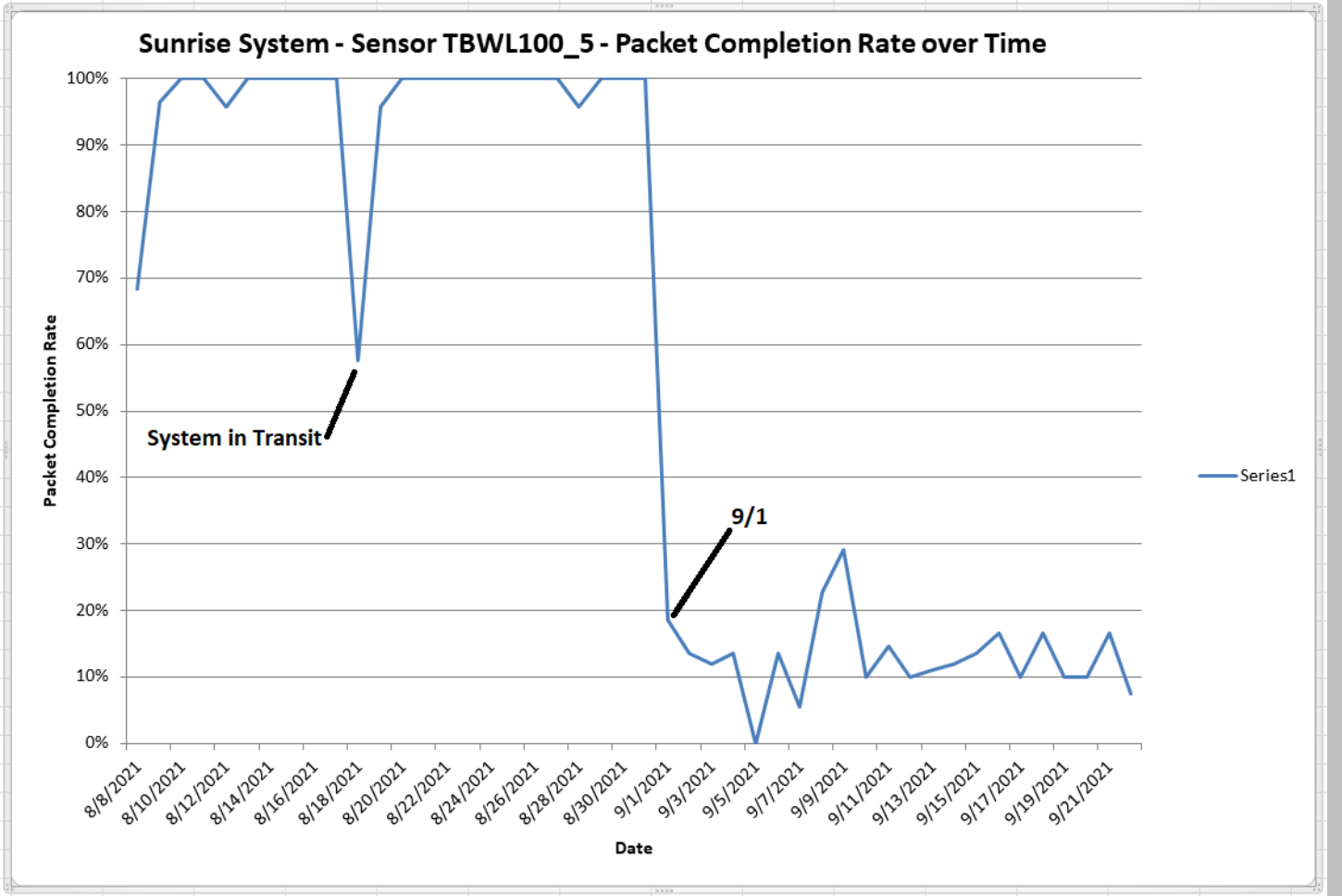
Sensor TBHH100\_5



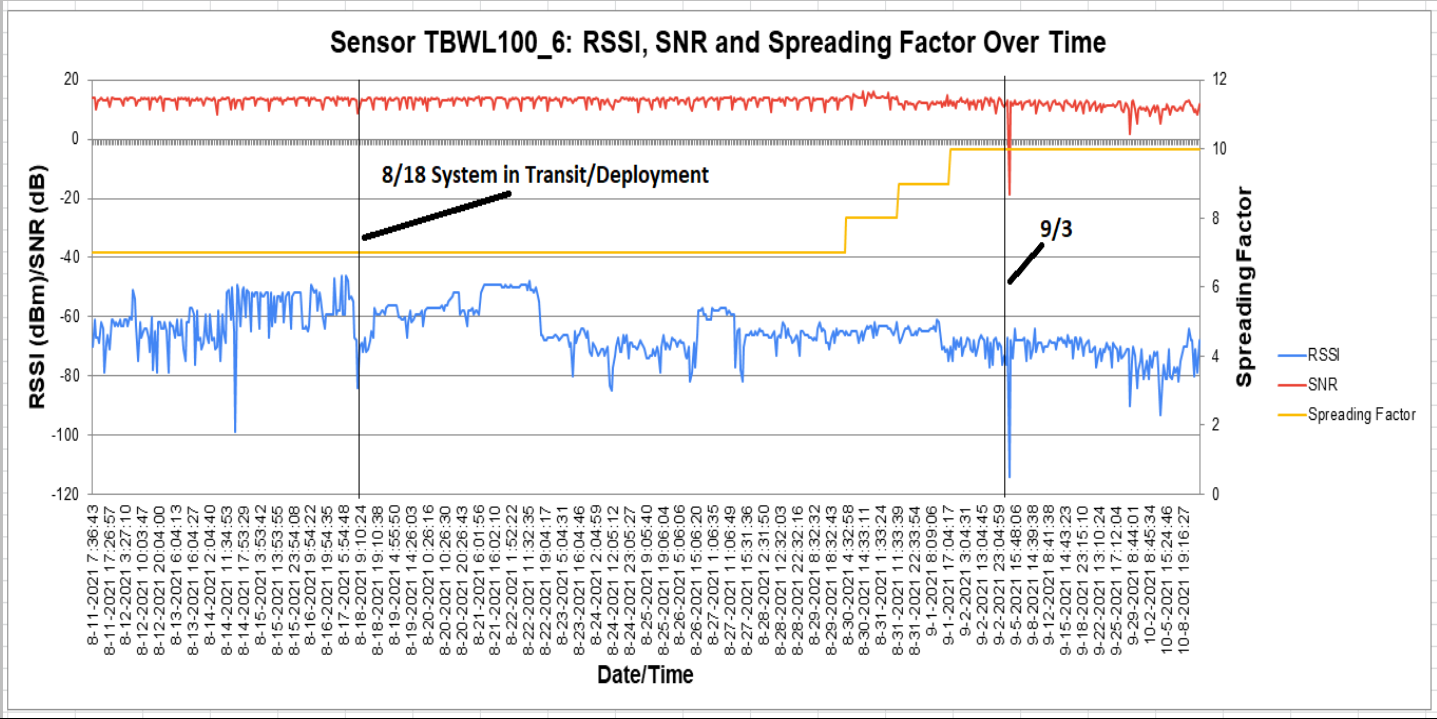
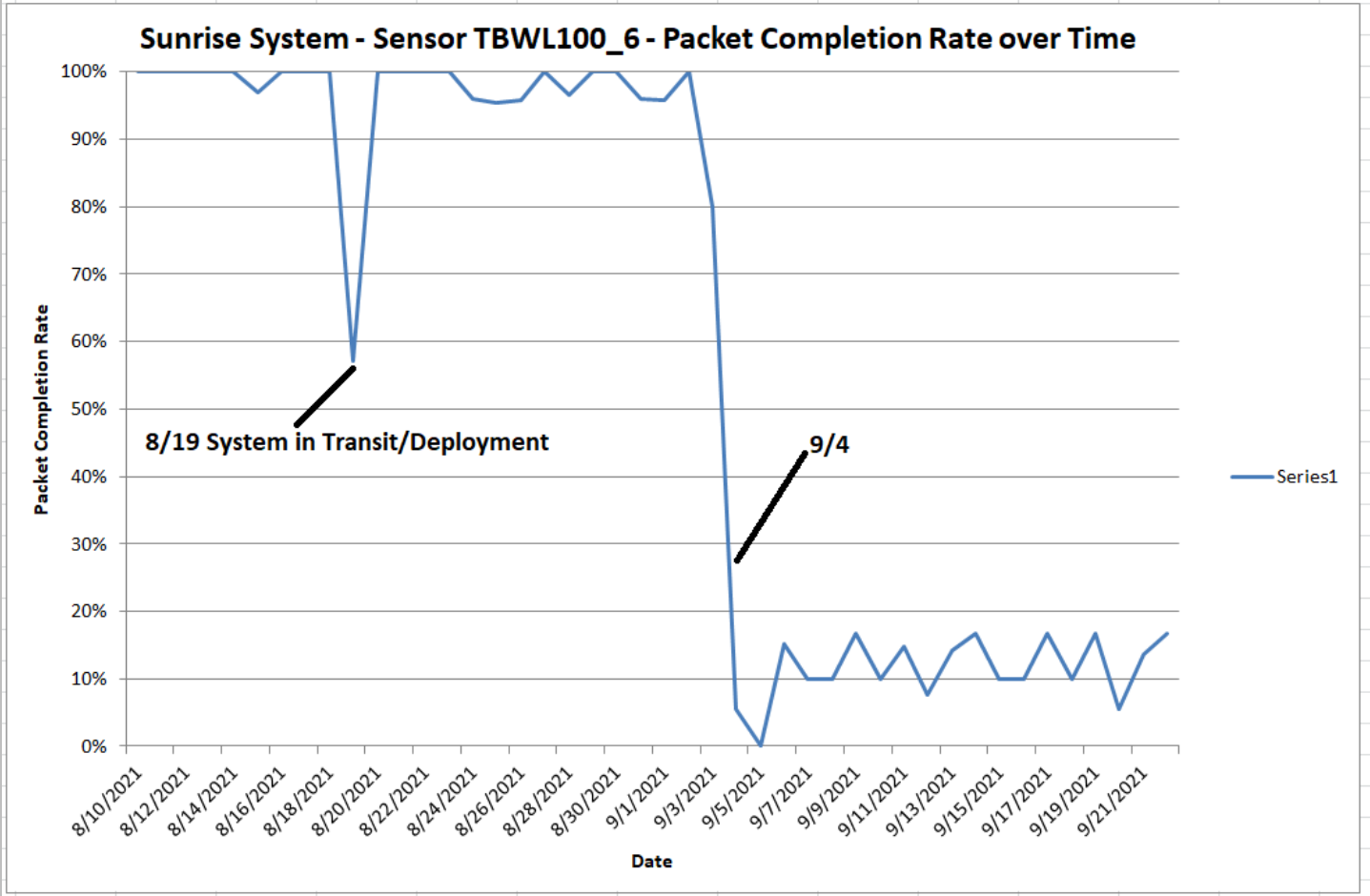
Sensor TBHV110\_5



Sensor TBWL100\_5



Sensor TBWL100\_6



## Appendix E – Data Files

The table below lists the log files used to derive the charts and analyses in this report. These files can be accessed in GitHub at the following location:

<https://github.com/mikedsp/helium/tree/master/Browan%20Sensor%20Performance%20Analysis%20on%20the%20Helium%20Network>

Log ID	Log File Name	Description
1	20210911_Hotspot and DC Tracker.xlsx	<p>Daily readings of sensor statistics (Frame Up, Frame Down, Packets Transferred, and DC used) from the sensors connected to the Helium Production Console – including the sensors in the Longview System. Data is from 7/22/20 thru 9/11/21. Note that devices not used in this report have their columns hidden on the devices tab for ease of reading.</p> <p>Contains the Packet Completion Rate chart for the Longview system and each sensor in the system</p>
2	20210922_Hotspot and DC Tracker – VIP.xlsx	<p>Daily readings of sensor statistics (Frame Up, Frame Down, Packets Transferred, and DC used) from the sensors connected to the Helium VIP Console – including the sensors in the Rogers and Sunrise Systems. Data is from 8/2/21 thru 9/22/21..</p> <p>Contains the Packet Completion Rate chart for the Rogers and Sunrise systems and each sensor in those systems</p>
3	20211019_Log_Longview_SensorDataFlow.xlsx	<p>Log of data from all sensors in the Longview system from 7/7/21 thru 10/19/21. Useful to see IoT network characteristics such as Hotspot name and sensor signal characteristics.</p> <p>Note that this log was started a couple months after the Longview system was deployed.</p>
4	20211012_Log_RogersHome_SensorDataFlow.xlsx	<p>Log of data from all sensors in the Rogers system starting from when the system first went online through 10/12/21. Useful to see IoT network characteristics such as Hotspot name and sensor signal characteristics.</p> <p>Contains the sensor SNR/RSI/Spreading Factor charts for the sensors in the Rogers system</p>
5	20211013_Log_SunriseFamilyFarm_SensorDataFlow.xlsx	<p>Log of data from all sensors in the Sunrise system starting from when the system first went online through 10/13/21. Useful to see IoT network characteristics such as Hotspot name and sensor signal characteristics.</p> <p>Contains the sensor SNR/RSI/Spreading Factor charts for the sensors in the Sunrise system</p>
6	20210908_Log_TBHH100.xlsx	<p>Log of data from all the TBHH100 type sensors. Data is from 2/2/21 thru 9/8/21.</p> <p>Contains the sensor SNR/RSSI charts for the TBHH100 sensors in the Longview system: TBHH100_7 and TBHH100_8</p>
7	20210916_TBHV110-	Log of data from all the TBHV110 type sensors. Data is from 12/26/20



	fromHelium.xlsx	thru 9/16/21.  Contains the sensor SNR/RSSI charts for the TBHV110 sensor in the Longview system: TBHV110_4
8	20210912_Log_TBWL100.xlsx	Log of data from all the TBWL100 type sensors. Data is from 2/14/21 thru 9/12/21.  Contains the sensor SNR/RSSI charts for the TBWL100 sensors in the Longview system: TBWL100_7, TBWL100_8, TBWL100_9, and TBWL100_10

Table D1 – Log files Used for Charting and Analysis in this Report