Chapter 5

EPLRS Operational Capacities

This chapter focuses on the operational capacities of the EPLRS NCS and RS. Performance and capacities characterize EPLRS operational capacities. This chapter covers tracking accuracy of the system while operating at the different operational capacities.

ABSOLUTE MAXIMUM PERFORMANCE AND CAPACITIES

5-1. EPLRS can perform these optimum capacities under ideal conditions. These capacities are based on hard limits, such as the maximum rates that messages can be sent out from the NCS or the maximum number of message units the NCS can store based on memory table size limitations.

5-2. For example, the number of active message units per NCS is limited to the absolute maximum of 470 units. The system planner should not use the absolute maximum performance and capacity for normal planning purposes. Instead, the planning should be based on the practical maximum performance and capacity.

PRACTICAL MAXIMUM PERFORMANCE AND CAPACITIES

5-3. These capacities are based on real-world conditions to include weather, terrain, pace of operations, and operational constraints/losses. For example, when an NCS sends out messages, the RS may not always be able to receive these messages due to interference, noise, and other factors.

5-4. For planning purposes, the system planner needs to understand the practical maximum performance and capacity. In addition, the system planner needs to ensure enough spare capacity is available for contingencies that may occur.

COMMUNICATIONS CAPACITIES

5-5. At the network level, communication capacity is defined in terms of throughput and is dependent on the number of RSs in the network. For example, suppose you have a community that has 250 RSs with a resource allocation of 25 percent group-addressed communication requirements and 75 percent duplex communication requirements. This community has a practical maximum capacity of 300 kilobits per second (Kbps) in support of duplex circuits and 450 Kbps in support of group-addressed communication circuits.

5-6. At the RS level, needline and RS capacities are defined by the highest throughput that needlines and RSs can have in a manageable network. The available time resources are the limiting factor on needline capacity. Individual EPLRS group-addressed needlines can support data transfers at rates up to 3,840 bits per second (bps). Individual EPLRS duplex needlines

are capable of supporting acknowledged data transfers at rates up to 1,920 bps. Individual EPLRS high data rate (HDR) needlines (MSG, P-P, and carrier sense multiple access [CSMA]) are capable of supporting data transfer rates up to 57,600 bps.

5-7. The RS supports multiple needlines simultaneously (up to a maximum of 32), depending on the allocation of LTSs assigned to group-addressed and duplex communications and allocation of LTSs to HDR needlines.

CONTROL NETWORK PERFORMANCE AND CAPACITIES

5-8. The NCS uses the EPLRS control network to send commands, messages, POS/NAV responses, and free-text messages to RSs. It is also used to receive reports (status, needline failure, and TOA reports) and messages (POS/NAV requests and free-text messages) from RSs. EPLRS requirements run the control network performance and capacities. Performance and capacity are primarily limited by–

- How fast the NCS can send messages to RSs.
- Amount of storage available in the NCS and RS.
- Accuracy of the TOA measurements.

5-9. The system planner must understand the EPLRS control network performance and capacities shown in Table 5-1. Factors that affect these capacities include–

- **Control network build rate**. A function of how many messages must be sent to each RS, how long it takes the NCS to send each message out to the RS, and how many RSs need to be brought into the control network.
- **Active units' limit per NCS**. A function of the flexibility to acquire new units and delete old units and the maximum table size in the RTEP software for active units per NCS.
- **Active units limit per division**. A function of the flexibility to acquire new units and delete old units and the maximum table size in RTEP for active units per division. In addition, some allocation must be made for non-active units, such as PDIs.
- **System area coverage**. A function of coordinate conversion limitations and operational needs.
- **Control network output message generation**. A function of the number of outbound message opportunities and the RSs ability to receive them.
- **Position accuracy**. A function of TOA measurement precision, terrain, interference, scatter, and other RF propagation characteristics.
- **Position updates at the NCS**. A function of the number of RSs and the number of position reports the NCS can receive as determined by the control net reporting structure.

Table 5-1. Control Network Performance and Capacities

Parameter	Absolute Maximum	Practical Maximum
Control network build rate	192 RSs per minute	100 RSs per minute
Active units limit per NCS	470	460
Active units limit per division	999	900
System area coverage	400 kilometers (km) x 400 km	47 km x 47 km (ground), 300 km x 300 km (air)
NCSs in a division	7 total	4 active (at any one time)
Position accuracy in CEP	3 meters	5 to 15 meters
Position updates (at NCS)	64 per second	35 per second
Communication network build rate	240 sites per minute localized	60 sites per minute in a brigade area
NCS needline library size	2000 per division	1900 per division
RS circuit assignments (RCAs)	32 ADDSI or 27 (1553B) communications circuit assignments (CCAs) 34 RCAs	30 (ADDSI) or 27 (1553B) CCAs 30 RCAs
RS communication throughput with communication LTS allocations: 2 LTSs duplex 2 LTSs simplex	6400 bits per second composed of: 3840 bps duplex 2560 bps simplex	3600 bps composed of: 1800 bps duplex 1800 bps simplex
Throughput with network communications LTS allocation: 2 LTSs duplex 2 LTSs simplex	840 kilobits per second composed of: 240 kbps duplex 600 kbps simplex	370 kbps composed of: 65 kbps duplex 305 kbps simplex
Total local subnet assignments	32 local subnets per division, with eight RSs per local subnet	30 local subnets per division with four to seven RSs per local subnet

CONTROL NETWORK INITIAL BUILD

5-10. To provide control and position location services quickly for the entire community of assigned RSs, a rapid network build is necessary. EPLRS provides this rapid build ability even under ECM conditions. The initial build of the control network for the normal EPLRS community can be achieved within five minutes under benign conditions (no ECM), with a rebuild taking less than three minutes. This allows the EPLRS to support real-time data distribution between network units in a very short time.

Initial Network Build, With Keys

5-11. Normally, RSs deploy with their current rekey and command keys. The RS's firmware saves the keys, even if powered down, and does not need to reacquire them unless the RS is zeroized. Prior to a large initial network build, the RSs should be brought into the net using an NCS to verify proper operation, including proper keying. This enables the RSs to acquire their current rekey and command keys prior to actual deployment. To become a fully participating member of the control network during initial deployment, a keyed RS must –

- Acquire the network's time and cryptographic synchronization via the network entry messages. This step includes receiving the time of day (TOD) and master unit identifier (MUID) message, transmitting the URR message, and receiving the UAK messages. This is a subtotal of three messages.
- Receive two PLAs and four to eight cross-link assignments from the NCS. This is six to eight additional messages.
- Send a status message to the NCS. This is one additional message.
- Receive various other control commands from the NCS. Five messages must be sent. These include three user command messages (UCMs), one user transmission command (UTC), and one additional message needed to send other control commands (mode command).

Initial Network Build Rate, With Keys (Absolute Maximum)

5-12. The fastest control network build rate occurs when the RSs already have their rekey and command keys and their communication assignments. In this situation, the absolute maximum control network build rate is a function of how many messages must be sent to each RS to bring it fully into the control network. It is also a function of how long it takes to send these messages to each RS.

5-13. The time it takes to send out network entry messages is negligible. It is a parallel process because the ECRU in the NCS and each active RS in the network sends out messages many times each second. The limiting factor is the number of messages that need to be sent to each RS from the NCS. There are three UCMs, each consisting of PLAs and cross-link assignments (three link assignments per UCM). In addition, one message is needed to send other control commands (mode command). The total number of messages per RS is 3 + 1 + 1 = 5 messages.

Initial Network Build Rate, With Keys (Practical Maximum)

5-14. The fastest control network build rate is limited by–

- Not all units hearing the messages that the NCS sent out the first time and the messages having to be repeated.
- Times that RTEP sends out messages not always aligning with the times that specific RSs can receive the messages, thus causing the RTEP to be idle during a possible transmit opportunity.
- RSs requesting EPLRS services during network build that would add to the number of messages the RTEP must generate in this period. In order to build the full network, it is sometimes necessary to send out new commands to RSs after sending out the five earlier messages, causing the number of messages per RS to increase. For these reasons, a more practical maximum control network build rate is about one half of the absolute maximum or about 100 RSs per minute under benign conditions.

Initial Network Build, Without Keys

5-15. In this situation, where the RSs are not fully keyed, the initial network build takes longer than the initial network build with keys. Each RS must receive the same messages indicated in the four steps listed under Initial Network Build, With Keys before becoming a particular member of the control network. Additionally, each RS receives a rekey key from the NCS. Upon receipt of the rekey key, the RS loads it, causing it to momentarily drop out of the network timing synchronization. Each RS must repeat these same steps again. When the RS indicates it has a rekey key, the NCS will send it a command key. The network build for an individual RS is then complete. Table 5-2 shows the rate of control network builds with and without keys.

Table 5-2. Initial Control Network Build

Parameter	Absolute Maximum	Practical Maximum
Control network build rate, with keys	192 RSs per minute	100 RSs per minute
Control network build rate, without keys	77 RSs per minute	40 RSs per minute

COMMUNICATIONS NETWORK PERFORMANCE AND CAPACITIES

5-16. The EPLRS communications network performance and capacities are driven by EPLRS requirements and are limited primarily by–

- The number of RSs and relays available.
- How fast the NCS can send messages to RSs.
- The amount of storage available in the NCS and RS.

5-17. The system planner and general-purpose user (GPU) should understand the EPLRS communication network performance and capacities shown in Table 5-3.

Table 5-3. Communications Network Performance and Capacities

Parameter	Absolute Maximum	Practical Maximum
NCS needline communicants	2 alternate NCSs 7 RSs	2 alternate NCSs 1 CC 1 SYSCON 3 RSs
Communication network build rate	240 per minute localized area	60 per minute brigade area
Total active needlines	850 per NCS	750 per NCS
NCS library size	2000 per division	1900 per division
RS circuit assignments	32 (ADDSI) or 27 (1553B) CCAs 34 RCAs	30 (ADDSI) or 27 (1553B) CCAs 30 RCAs
RS communications throughput with communications LTS allocation:		
3 LTSs duplex 1 LTS simplex	7040 bps composed of: 5760 bps duplex 1280 bps simplex	3600 bps composed of: 2700 bps duplex 900 bps simplex
or	or	or
2 LTSs duplex and 2 LTSs simplex	6400 bps composed of: 3840 bps duplex 2560 bps simplex	3600 bps composed of: 1800 bps duplex 1800 bps simplex
	or	or
	5760 bps composed of: 1920 bps duplex 3840 bps simplex	3600 bps composed of: 900 bps duplex 2700 bps simplex

Table 5-3. Communications Network Performance and Capacities (Continued)

Parameter	Absolute Maximum	Practical Maximum
Network communications throughput with communications LTS allocation:		
	660 kbps composed of:	250 kbps composed of:
	360 kbps duplex plus	100 kbps duplex plus
	300 kbps simplex	150 kbps simplex
	or	or
2 LTSs duplex and	780 kbps composed of:	370 kbps composed of:
2 LTSs simplex	395 kbps duplex	65 kbps duplex
	600 kbps simplex	305 kbps simplex
	or	or
	1020 kbps composed of:	490 kbps composed of:
1LTS duplex	120 kbps duplex	30 kbps duplex
3 LTSs simplex	900 kbps simplex	460 kbps simplex
Total local subnet Assignments	32 local subnets/division, with 8 RSs/local subnet	30 local subnets/division with 4 to 7 RSs/local subnet

COMMUNICATIONS NETWORK BUILD

5-18. The EPLRS communications network build requires that RSs already have their communication assignments, or RSs must receive them from the NCS via the control network. RSs quickly coordinate relays for the needline via the communications network. RSs establish the coordination net on the communications network to set up relays for user-to-user communications.

5-19. RSs use distributed routing (also known as communication circuit coordination) to find, assign, and maintain relay paths without NCS support. Distributed routing is initiated in response to activating a needline or a circuit failure.

5-20. The endpoint RS transmits a circuit activation request. The circuit request message is retransmitted by potential relay RSs. The destination RS receives the circuit request message and transmits a circuit accept message. The circuit-accept message follows the same path as the circuit request message. The source RS receives the circuit accept message and the path has been assigned. Distributed routing takes place on the coordination net that is established on the communications network.

Communications Network Build Events

5-21. EPLRS communications network build depends on the–

- RS sending a message to the NCS, indicating a desire to activate a needline.
- NCS generating and transmitting CCA commands and COI keys to the appropriate endpoint RS that is active in its control network. (Or the NCS sending the data to another NCS if an endpoint RS is not active in its community.)
- RS coordinating a relay path among themselves using the coordination network.
- Needline being ready to transfer user data.

Communications Network Build Rate (Absolute Maximum)

5-22. The fastest communication needline build rate occurs when the RSs already have their communication assignments and COI keys and only need to coordinate relays for each active assignment. This is the typical condition if needlines have been set up prior to deploying. The absolute maximum communications network build rate under ideal conditions is how many messages must be sent from RS to RS to coordinate a relay path and how long it takes to send these messages.

5-23. The minimum number of messages that need to be sent to each RS is one per circuit, sent over the coordination network. The maximum rate of messages sent by an RS and received by another RS on the coordination network is one coordination message per frame in a localized area to avoid mutual interference.

Communications Network Build Rate (Practical Maximum)

5-24. Due to mutual interference, RSs not hearing the circuit coordination messages in all frames limit the needline build rate. Thus, some coordination network messages will have to be repeated. It is more practical to assume an average of one successful circuit coordination per frame instead of every coordination being successful. This is more realistic since, with mutual interface, sometimes two or more circuits may coordinate successfully and sometimes one circuit coordination will be successful. A typical localized area, with regard to mutual interference, is a brigade area.

5-25. An RS with potentially open communications parameters not listening for a circuit coordination message in a particular frame also limits the needline build rate. This usually occurs if the RS already has heard a coordination message in that frame for another circuit. It is not practical to assume that every RS will hear only the coordination message for which it can sign up as relay. If a RS receives a coordination message in a frame, it will ignore all other coordination messages in that frame. It is more practical to assume an average of one successful circuit coordination per frame instead of assuming every coordination attempted in a frame will be successful.

5-26. The circuit assignment received by an RS not working also limits the needline build rate. This causes the RS to coordinate new resources in addition to coordinating a relay path. The need to repeat coordination reduces the effective build rate by about 5 to 10 percent of the optimal rate.

5-27. The need to coordinate paths more than once because mutual interference causes already coordinated paths to fail limits the needline build rate. The need to coordinate more than once for the same circuit reduces the effective build rate by about another 5 to 10 percent of the optimal rate.

5-28. RSs that do not have their CCA commands or COI keys already stored limits the needline build rate. This causes the NCS to have to send new assignments to these RSs. Sending new circuit assignments from the NCS to RSs does not slow the communications needline build rate very much. The NCS can practically send 500 messages per minute, and circuit assignments take four messages (three for the COI key and one for the CCA command itself). Thus, 125 circuit assignments per minute could be sent out, with more being sent out under heavy load conditions. Given these factors, the practical maximum communication needline build rate is about 60 needlines per minute for a brigade area.

NETWORK CONTROL SYSTEM LIBRARY CAPACITIES

5-29. The NCS library gives the system planner the operational flexibility of the EPLRS. However, certain limitations exist because of the size of each NCS library section. Table 5-4 shows the NCS library's capacities.

Table 5-4. NCS Library Capacities

Parameter	Absolute Maximum	Practical Maximum
NCS control network communications	1 alternate NCS 5 other NCSs	1 alternate NCS 2 other NCSs
Active units limit per NCS	470	460
Active units limit per division	999	900
NCSs per division	7 total	4 active

OUTBOUND MESSAGE GENERATION PERFORMANCE AND CAPACITIES

5-30. The NCS response time for 90 percent of all received data input (DI) requests is less than 120 seconds under ECM conditions and heavy traffic. The maximum practical output message generation is 500 messages per minute. This allows EPLRS to demonstrate quick response to operator requests even under heavy jamming and high message activity.

5-31. EPLRS supports up to 12 corridors, 10 zones, and 12 lanes, and is sized for 104 PDIs. Users can request and receive navigational information relative to a PDI. In addition, EPLRS supplies position and B/R information. This position reporting and navigation information is disseminated to the user in

response to DI messages, and performance depends on the NCS's ability to service these requests.

5-32. Response time for DI requests is the time between a RS sending in a DI message and the time it receives a response from the NCS. Factors that affect response time include deployment, scheduling efficiency, report rates, and message priority protocols. The average response time for a typical RS is between 5 and 8 seconds. Table 5-5 shows response times to DI requests for normal and heavy activity. The response times given are based on DI messages already received at the NCS.

Table 5-5. Response Time to DI Requests

Normal Operations (50 DI Requests per Minute) Threat Environment		
Request Activity	**Benign**	**ECM**
Respond to 50 percent of all received requests (normal)	10 seconds	30 seconds
Respond to 90 percent of all received requests (heavy)	20 seconds	60 seconds
Heavy Activity (100 DI Requests Per Minute) Threat Environment		
Request Activity	**Benign**	**ECM**
Respond to 50 percent of all received requests (normal)	20 seconds	60 seconds
Respond to 90 percent of all received requests (heavy)	60 seconds	120 seconds

CONTROL NETWORK OUTPUT MESSAGE GENERATION (ABSOLUTE MAXIMUM)

5-33. The maximum and practical capabilities are based on available message transmit resources. The number of control network output messages generated is a function of the number of outbound transmit opportunities for the NCS.

CONTROL NETWORK OUTPUT MESSAGE GENERATION (PRACTICAL MAXIMUM)

5-34. The practical maximum number of relayed control network output messages generated is 960 per minute. Since messages must be relayed for those RSs that cannot receive directly from the NCS, the number of practical transmit opportunities is somewhere between 960 and 1920 per minute depending on environmental factors such as terrain and interference.

5-35. The times when the RTEP sends out messages do not always align with the times that specific RSs can receive them. This causes RTEP to be idle during some possible transmit opportunities, thereby reducing the number of

practical control network output messages generated. Under normal conditions, there is generally no need to send out all the messages generated.

5-36. For those reasons, a more practical number of control network output messages generated is about one quarter of the absolute maximum, or about 500 messages per minute. Under some conditions, such as after a jamming incident or a network build, the rate is higher.

POSITION TRACKING ACCURACY CAPACITIES

5-37. EPLRS can provide accurate position and navigation information for locating and controlling units of a dynamic network in a tactical environment. EPLRS position location accuracy is highly dependent on the surrounding terrain and reference ground community location.

NOTE: The GR-RS resources alone are not sufficient and are not intended to provide all of the needed grid reference coverage, so the system must rely on other military units as grid reference points. Units that make good grid references are those that use surveyed points as the locations for their systems such as field artillery and engineer units.

5-38. In a static benign environment, the manpack surface vehicle and airborne RSs may approach the lower limits of absolute horizontal position accuracy. This accuracy is calculated using CEP as a measure. Absolute altitude accuracy is calculated using AEP as a measure.

5-39. CEP is the radius of that circle, centered on an RS's true position that contains 50 percent of the RS's horizontal position locations. The point farthest away from the RS's true horizontal position, but among the closest 50 percent, is the CEP radius.

5-40. AEP is the half width of that band centered on an RS's true altitude that contains 50 percent of the RS's calculated position locations. The distance from the point farthest away from the RS's true altitude, but among the 50 percent that are the closest, is used as the half width. The accuracy based on these measures is applicable to both the primary (20 km by 30 km or 47 km by 47 km) and extended (300 km by 300 km) operating areas.

5-41. When RSs are in a dynamic environment, the accuracy approaches the upper limits of their expected CEP and AEP. When RSs are in a dynamic environment, the accuracy approaches the upper limits of their expected CEP and AEP. Table 5-7 shows the position location accuracy.

Table 5-7. EPLRS Position Location Accuracy

RS Type	(X, Y)[1]	(Z)[2]	RS Deployment
MP-RS	10-30 meters	10-30 meters	Primary Area
SV-RS	10-30 meters	10-30 meters	Primary Area
AV-RS (all platforms)	25-100 meters	10-30 meters	Primary Area
AV- RS (all platforms)	100-200 meters	15-90 meters	Extended Area

[1] Absolute horizontal position accuracy (using CEP).

[2] Absolute Altitude Accuracy (using AEP).

POSITION ACCURACY (ABSOLUTE MAXIMUM)

5-42. The absolute maximum position accuracy of the EPLRS is a function of the TOA measurement precision. Since one TOA measurement count equals 12.5 nanoseconds (nsec), this equals approximately 4 meters one-way or 2 meters two-way in range.

POSITION ACCURACY (PRACTICAL MAXIMUM)

5-43. Since the real world creates some differences in TOA measurement values (varied terrain, reflections, multi-path, diffraction, scatter, and geometric dilution of precision), the practical maximum position accuracy is between 5 and 15 meters for ground units.

POSITION UPDATES (ABSOLUTE MAXIMUM)

5-44. The absolute maximum position updates that can be generated are equal to the maximum position updates from the RSs UMR messages.

POSITION UPDATES (PRACTICAL MAXIMUM)

5-45. The absolute maximum position updates are not seen in the field. The network would not be full capacity (about 74 percent full is better to allow for flexibility and growth) and there may be redundant TOA measurements for the same position update that could reduce the maximum seen. The practical number of position updates generated is about 35 per second.

SYSTEM AREA COVERAGE (ABSOLUTE MAXIMUM)

5-46. The absolute maximum system area coverage for which coordinate conversion is supported via the RTEP is 400 x 400 kilometers, and may be less depending on the affects of weather and terrain.

SYSTEM AREA COVERAGE (PRACTICAL MAXIMUM)

5-47. The practical maximum system area coverage needed is 300 x 300 square kilometers. The practical maximum area capable of being supported for ground coverage is 47 x 47-square kilometers.