D-STAR System

Technical Requirements for the Wireless System

1.1 Voice Communication

1.1.1 General Terms

(1) Communication Method
Half-duplex, digitized voice transmissions.

(2) Communication Contents
Digitized voice/audio signals and short data messages are supported. Voice and audio streams are transmitted synchronously to support communications quality reproduction. Data and voice/audio transmissions are interleaved.

1.1.2 Transmitting Equipment

(1) Modulation methods
GMSK
QPSK
4FSK

(2) Data rate
Maximum of 4.8 Kbps

(3) Voice encoding method
AMBE (2020) converting at 2.4 Kbps
FEC at 3.6 Kbps

(4) Occupied bandwidth
Maximum of 6 KHz

1.1.3 Tx / Rx Switching time

Less than 100ms.

1.2 Data Communication

1.2.1 General Terms

(1) Communication Method
Simplex

(2) Communication Contents
Digital data stream is supported.

1.2.2 Transmitting Equipment

(1) Modulation method
GMSK
QPSK
4FSK
(2) Data rate
Maximum of 128 Kbps

(3) Occupied bandwidth
Maximum of 150 KHz

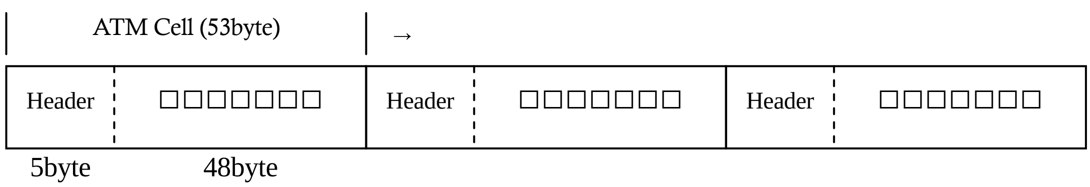
1.1.3 Switching time (Tx-Rx)
Less than 50ms.

1.3 Backbone communication

1.3.1 General Terms
(1) Transmission Method
Full duplex.
(2) Transmission Contents
Backbone communication between repeaters containing multiplexed digitized voice/audio, user data, and link control data signals.

1.3.2 Transmitting Setup
(1) Output power
Complies with FCC regulations.
(2) Modulation method
GMSK
(3) Data rate
Maximum of 10Mbps
(5) Occupied bandwidth
Maximum of 10.5MHz

1.3.3 Multiplexing Method
The multiplexing method for backbone links is an ATM. The details of the specifications comply with the ATM protocol. Digitized voice/audio signals should be given the highest transmission priority.
If more data is required, refer to ATM standards.



2. System Interconnection Requirements

2.1 Wireless Communication Packet

The frame structure of the wireless packet is below.

2.1.1 Frame structure of a data packet

Radio Header											Data					FCS
Bit Syn	Frame Syn.	Flag 1	Flag 2	Flag 3	ID					P_FCS	E_Len	MAC Header			Data frame	CRC
					Destination Repeater Callsign	Departure Repeater Callsign	Companion Callsign	Own Callsign 1	Own Callsign 2			SA	DA	Type		
64bit	15bit	1	1 byte	1	8byte	8byte	8byte	8byte	4byte	2byte	2byte	6byte	6byte	2byte	46-1500byte	4byte

|←―――――― error correction 660bit ――――――

The explanation of the data frame structure the Radio Header follows.

(1) **Bit Syn**. (Bit synchronization): Repeated standard 64-bit synchronization pattern (for GMSK 1010, for QPSK 1001). Transmission direction is from left to right.

(2) **Frame Syn**. (Frame synchronization) : 15bit pattern (111011001010000). Transmission direction is from left to right.

(3) **Flag 1** (8 bit): Flag 1 uses upper 5 bits and lower 3 bits separately.
A detailed explanation follows.

bit 7(MSB)	Distinguishes between voice and data communications. 1 indicates data, 0 indicates voice.
bit 6	Identifies if the signal goes through a repeater or is a direct communication between terminals.(1for repeater, 0 for terminal)
bit 5	Recognizes if communication interruption exists. 1 indicates interruption, 0 indicates no interruption.
bit 4	Identifies control signal/data signal.1 represents control signal and 0 represents regular data signal.(Voice signal included)
bit 3	1 represents an urgent priority signal,0 represents a normal priority signal. For signals with a "1" in this position, the receiver will open squelch etc.

Note, Urgent signal in this document does not mean "Urgency signal" as defined in International Radio Law. It means an urgent priority signal for use in emergency communications.

bit 2,1,0	111=repeater station control flag, while the repeater is controlled, the flag is "111" and the data frame contains control data.

110=Auto reply
101=Unused(spare)
100=Resend flag, requests resending previous frame
011=ACK flag,Treated as ACK flag
010=No reply flag, Indicates no reply is available
001=Relay unavailable flag, Indicates unsuitable relaying conditions.
000=NULL, No information.

	Upper bit				
Bit	7	6	5	4	3
1	Data	Relay	Interruption	Control	Urgent
0	Voice	Direct	No interruption	Control	Urgent

Lower bit				
2	1	0	Function	Note
1	1	1	Repeater Control	Repeater Control Mode
1	1	0	Auto Reply	Used for Auto Reply
1	0	1	(Unused)	(Unused0
1	0	0	Resend	Requests Resend
0	1	1	ACK	ACK flag
0	1	0	No Response	Indicates No Response Available
0	0	1	Relay Unavailable	Indicates Relay Unavailable
0	0	0	NULL	NULL

(4) **Flag 2**

Flag 2 is for future expandability and is defined below.

Bit	7	6	5	4	3	2	1	0	Note
Flag									Default

a. flag is used as an format descriptor. This is available not only for the increase and decrease of a figure of callsign but also for ID, which is not used as callsign rather than numeric.

b. flag is used only a creator or a manufacturer of the equipment.

(5) **Flag 3**

Flag 3 is used to match control functions to protocol versions, which may be upgraded in future software versions.

Bit	Meaning	Function
00000000	No	Default

	Function	
00000001	Undefined	Use for future expansion
to		
11111111		

(6) "**Destination repeater Callsign**" can have a maximum of 8 ASCII letters and numbers. Blanks should be filled with a space character. In the case of direct communication, it inserts "   " and fills the blanks with a space character. The use of this field is described in section 2.2.

(7) "**Departure repeater Callsign**" can have a maximum of 8 ASCII letters and numbers. Blanks should be filled with a space character. In the case of direct communication, it inserts "   " and fills the blanks with a space character. The use of this field is described in section 2.2.

(8) "**Companion Callsign**" can have a maximum of 8 ASCII letters and numbers. Blanks should be filled with a space character. The use of this field is described in section 2.2.

(9)"**Own Callsign 1**" can have a maximum of 8 ASCII letters and numbers. Blanks should be filled with a space character. This field same as voice frames.

(10) "**Own Callsign 2**" is used when to add suffixes to a callsign or an additional destination address information. "Own Callsign 2" can have a maximum of 4 ASCII letters and numbers. Blanks should be filled with a space character.

(11) **P_FCS** is the Radio Header CRC-CCITT checksum, computed by the following expression.

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

(12) The **data frame** of the packet is constructed as an Ethernet packet.

(13) **FCS** is the checksum of the Ethernet data payload. It is a CRC-32 checksum as defined in ISO3309 and is computed by the following expression.

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

2.1.2 Frame structure of voice packet

Radio Header											Data						
					ID												
Bit Syn	Frame Syn.	Flag 1	Flag 2	Flag 3	Destination Repeater Callsign	Departure Repeater Callsign	Companion Callsign	Own Callsign 1	Own Callsign 2	P_FCS	Voice Frame	Data Frame	Voice Frame	Data Frame		Voice Frame	Data Frame
64bit	15bit	1	1	1	8byte	8byte	8byte	8byte	4byte	2byte	72byt	24byte	72byte	24byte		72byte	24byte

|← byte ——— error correction 660bit ———————→

The explanation of the voice packet including the voice and data frames follows:

(1) The Radio Header has the same frame structure as for the data packet.

(2) Data part includes 72-bit voice signal frames with a length of 20ms in order of their output from the CODEC according to the AMBE (w/FEC) specification. Data frames contain 24-bits of data.

(3) The first data frame and then every 21st data frame in a repeating cycle, are used only for synchronizing data for each modulation type. Synchronization corrects for the lag between transmission and reception, including the transit time of communications. This synchronized signal contains a 10-bit synchronized signals and two 7-bit Maximal-length sequences "1101000" patterns. (24 bits total). Transmission direction is from left to right.

(4) The data in a data frame is transmitted without modification from the input data. If the data is required as error correction or synchronization, these frames are processed before processing the data input.

(5) If the data signal length is greater than the length of the voice communication the transmitting switch is turned on until the completion of the data signal manually. The processing can be allowed automatically.

(6) The last data frame, which requires a means of terminating the transmission, is a unique synchronizing signal (32 bit + 15bit "000100110101111" + "0", making 48 bits) as defined by the modulation type. Transmission direction is from left to right.

2.2 Communication protocol

Note : In the following descriptions,_ (under-bar) indicates a space character, ASCII $20. If the callsign field has blanks between the callsign's last letter and last character in the field, the blanks should be filled with a space character.

2.2.1 Callsign

The Callsign field of the radio header of data and voice packets is used for packet routing. Except for the callsign in the "Own station" fields, callsigns generally have less than 6 letters (or 7 letters). The following paragraphs show how to interpret callsign fields:.

(1) "**Destination repeater Callsign**"

In zone communication, this field must be set to the callsign of the repeater utilized by the companion station.

If there are multiple repeaters in a repeater site, they are distinguished by last character, of "A", "B", "C", or "D". (Ex. W$1AAA_A , W$1AAA_D, etc.) The default character is "A".

(Explained callsign is not to exist as W$1AAA but only for examples)

When communicating outside the local zone, which is called zone to zone communication, this field must be set to the callsign of the zone repeater connected to a gateway and last character set to “G” to indicate communications via the gateway. (Ex. W$1AAA_G)

(2) ”**Departure repeater Callsign**”

This field must be set to the repeater callsign of the originating station.

If there are multiple repeaters in a repeater site, they are distinguished by last character of “A”, “B”, “C”, or “D”. (Ex. W$1AAA_A , W$1AAA_D etc.) The default character is “A”.

(3) ”**Companion Callsign**”

The field must be set the callsign of the companion station with which communication is desired. If the station has multiple radios,, they are distinguished by last character of “A”, “B”, “C”, “D”, “E”, or “F”. (Ex. W$1AAA_A , W$1AAA_F etc.)

When originating a non-directed call,, the field should contain “CQCQCQ”.

When calling CQ to a non-local zone, which is called zone to zone communication, prepend “/” to the destination repeater callsign. If there are multiple repeaters in a repeater site, they are distinguished by last character of “A”, “B”, “C”, or “D”. (Ex. W$1AAA_A , W$1AAA_D etc.) The default character is “A”.
To access a repeater with a local server, in “Companion Callsign”, the field should contain the repeater callsign and set last character to “S”. (Ex. W$1BBB_S)

(4) ”**Own Callsign 1**”

The “Own Callsign” field contains the own station’s callsign. If the station has multiple radios, they are distinguished by last character of “A”, “B”, “C”, “D”, “E”, or “F”. (Ex. W$1AAA_A , W$1AAA_F etc.)

(5) ”**Own Callsign 2**”

This field contains information to display as in after a “/ (slash)”. (Ex. W$1AAA_F / JD1 etc. Note: “/” is not displayed). The purpose of “Own Callsign 2” is to allow “Own Callsign 1” to contain as complete a callsign as possible. “Own Callsign 2” is not evaluated by the system’s identification functions.

Appendix

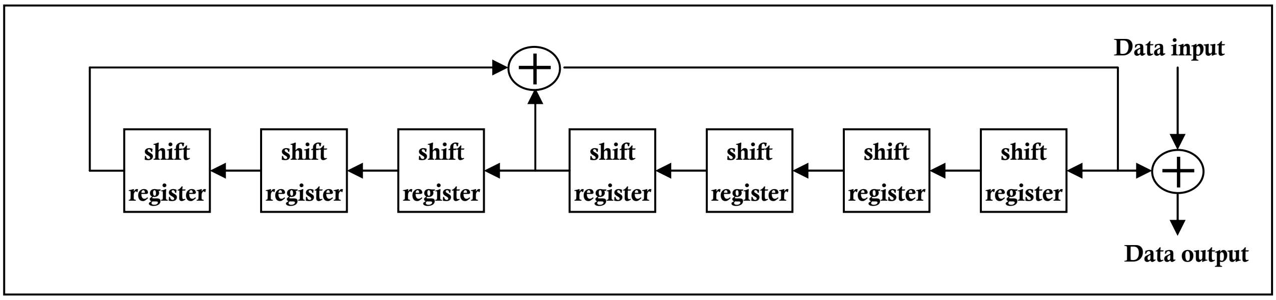
AP1 Scrambler

Scrambling is implemented as follows to eliminate errors when the same bit patterns are received continuously.

AP1.1 Scramble codes

$$S(x) = x^7 + x^4 + 1$$

Initialization defines . Initialization begins the scrambling process.



AP1.2 Data packet scrambling

Radio Header											Data					FCS
					ID							MAC Header				
Bit Syn	Frame Syn.	Flag 1	Flag 2	Flag 3	Destination Repeater Callsign	Departure Repeater Callsign	Companion Callsign	Own Callsign 1	Own Callsign 2	P_FCS	E_Len	SA	DA	Type	Data frame	CRC
64bit	15bit	1	1 byte	1	8byte	8byte	8byte	8byte	4byte	2byte	2byte	6byte	6byte	2byte	46-1500byte	4byte

|←―――――― error correction 660bit ――――――→

Scramble range

Initialization point

AP1.3 Voice packet scrambling

Voice packet scrambling includes the radio header and data frames except for synchronizing frames. Synchronized signals and the last frame are not scrambled.

Radio Header											Data						
					ID												
Bit Syn	Frame Syn.	Flag 1	Flag 2	Flag 3	Destination Repeater Callsign	Departure Repeater Callsign	Companion Callsign	Own Callsign 1	Own Callsign 2	P_FCS	Voice Frame	Data Frame	Voice Frame	Data Frame		Voice Frame	Data Frame
64bit	15bit	1	1	1	8byte	8byte	8byte	8byte	4byte	2byte	72byt	24byte	72byte	24byte		72byte	24byte

|←―――――― error correction 660bit ――――――→

scramble

Initialization Point

scram

Initialization point

AP2 Error Correction

Error correction for data voice packets is performed as follows.

The error correction range is from Flag 1 to P-FCS.

The error correction signal is interleaved with the packet data with a convolutional rate of 1/2, a constraint length of 3, and a depth of interleave of 24.

The structure of encoder

Convolution code

Convolutional code rate /

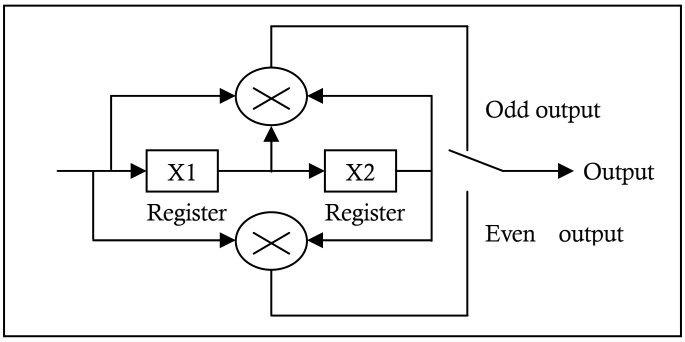
Constraint length

Handover bit

Generator polynomial

$G_1(D) = 1 + D + D^2$

$G_2(D) = 1 + D^2$



Composing process

(1) X1, X2 registers must be set to zero before encoding.

(2) Feed header data into the encoder beginning with the LSB.

(3) Following the header data, including P_FCS, input two zero bits.

AP3 Interleave process

To reduce continuous burst errors during the radio header, the interleaving process specified by the following interleave matrix is used. The interleave process operates independently of the error correction process.

To interleave transmit error correction, input the packet data stream from left top to the bottom. Read the interleaved data stream from left top to right.

To separate the error correction data and original data stream, input from the received data stream from the left top to right. Read the output data stream from the left top to the bottom.

interleave structure MATRIX

(ms)		0.2	0.4	0.6	0.8	1	1.2	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	4	4.2	4.4	4.6	4.8	5	5.2	5.4	5.6	5.8
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
0.21	0	0	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576	600	624	648
6.03	1	1	25	49	73	97	121	145	169	193	217	241	265	289	313	337	361	385	409	433	457	481	505	529	553	577	601	625	649
12.1	2	2	26	50	74	98	122	146	170	194	218	242	266	290	314	338	362	386	410	434	458	482	506	530	554	578	602	626	650
18.1	3	3	27	51	75	99	123	147	171	195	219	243	267	291	315	339	363	387	411	435	459	483	507	531	555	579	603	627	651
24.1	4	4	28	52	76	100	124	148	172	196	220	244	268	292	316	340	364	388	412	436	460	484	508	532	556	580	604	628	652
30.2	5	5	29	53	77	101	125	149	173	197	221	245	269	293	317	341	365	389	413	437	461	485	509	533	557	581	605	629	653
36.2	6	6	30	54	78	102	126	150	174	198	222	246	270	294	318	342	366	390	414	438	462	486	510	534	558	582	606	630	654
42.2	7	7	31	55	79	103	127	151	175	199	223	247	271	295	319	343	367	391	415	439	463	487	511	535	559	583	607	631	655
48.3	8	8	32	56	80	104	128	152	176	200	224	248	272	296	320	344	368	392	416	440	464	488	512	536	560	584	608	632	656
54.3	9	9	33	57	81	105	129	153	177	201	225	249	273	297	321	345	369	393	417	441	465	489	513	537	561	585	609	633	657
60.3	10	10	34	58	82	106	130	154	178	202	226	250	274	298	322	346	370	394	418	442	466	490	514	538	562	586	610	634	658
66.4	11	11	35	59	83	107	131	155	179	203	227	251	275	299	323	347	371	395	419	443	467	491	515	539	563	587	611	635	659
72.4	12	12	36	60	84	108	132	156	180	204	228	252	276	300	324	348	372	396	420	444	468	492	516	540	564	588	612	636	
75.7	13	13	37	61	85	109	133	157	181	205	229	253	277	301	325	349	373	397	421	445	469	493	517	541	565	589	613	637	
81.5	14	14	38	62	86	110	134	158	182	206	230	254	278	302	326	350	374	398	422	446	470	494	518	542	566	590	614	638	
87.4	15	15	39	63	87	111	135	159	183	207	231	255	279	303	327	351	375	399	423	447	471	495	519	543	567	591	615	639	
93.2	16	16	40	64	88	112	136	160	184	208	232	256	280	304	328	352	376	400	424	448	472	496	520	544	568	592	616	640	
99	17	17	41	65	89	113	137	161	185	209	233	257	281	305	329	353	377	401	425	449	473	497	521	545	569	593	617	641	
105	18	18	42	66	90	114	138	162	186	210	234	258	282	306	330	354	378	402	426	450	474	498	522	546	570	594	618	642	
111	19	19	43	67	91	115	139	163	187	211	235	259	283	307	331	355	379	403	427	451	475	499	523	547	571	595	619	643	
116	20	20	44	68	92	116	140	164	188	212	236	260	284	308	332	356	380	404	428	452	476	500	524	548	572	596	620	644	
122	21	21	45	69	93	117	141	165	189	213	237	261	285	309	333	357	381	405	429	453	477	501	525	549	573	597	621	645	
128	22	22	46	70	94	118	142	166	190	214	238	262	286	310	334	358	382	406	430	454	478	502	526	550	574	598	622	646	
134	23	23	47	71	95	119	143	167	191	215	239	263	287	311	335	359	383	407	431	455	479	503	527	551	575	599	623	647	

Lexicon

Gate way (GW)

Equipment of to connect between a zone repeater and the Internet. Usally it is normal PC including D-STAR GW softwares.

Zone

A region of connected multi repeaters by backbone repeaters.

Zone repeater

Connected a repeater to the Internet in a zone.

Repeater area

A region of available to access a repeater to the terminals.

Repeater site

A place of setting some repeaters and/or backbone repeaters.

Figure of System constitution

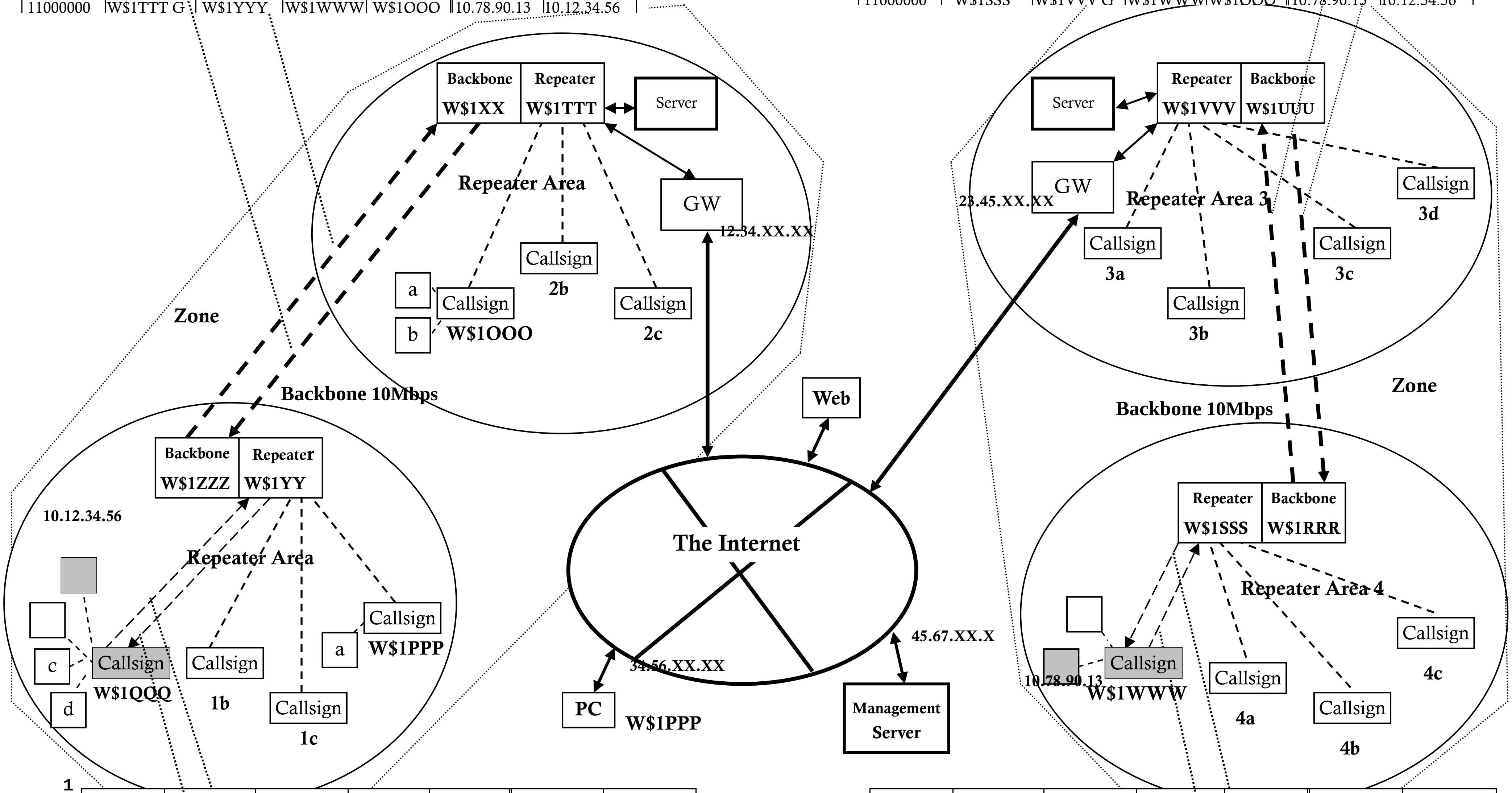
Flag	Destination	Departure	Companion	Own	Comp. IP	OwnIP
11000000	W$1YYY	W$1TTT G	W$1OOO	W$1WWW	10.12.34.56	10.78.90.13

2

Flag	Destination	Departure	Companion	Own	Comp. IP	Own IP
11000000	W$1TTT G	W$1YYY	W$1WWW	W$1OOO	10.78.90.13	10.12.34.56

Flag	Destination	Departure	Companion	Own	Comp. IP	OwnIP
11000000	W$1VVV G	W$1SSS	W$1OOO	W$1WWW	10.12.34.56	10.78.90.13

Flag	Destination	Departure	Companion	Own	Comp. IP	Own IP
11000000	W$1SSS	W$1VVV G	W$1WWW	W$1OOO	10.78.90.13	10.12.34.56



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Flag	Destination	Departure	Companion	Own	Comp. IP	Own IP
11000000	W$1TTT G	W$1YYY	W$1WWW	W$1OOO	10.78.90.13	10.12.34.56

Flag	Destination	Departure	Companion	Own	Comp. IP	Own IP
11000000	W$1YYY	W$1TTT G	W$1OOO	W$1WWW	10.12.34.56	10.78.90.13

Flag	Destination	Departure	Companion	Own	Comp. IP	Own IP
11000000	W$1SSS	W$1VVV G	W$1WWW	W$1OOO	10.78.90.13	10.12.34.56

Flag	Destination	Departure	Companion	Own	Comp. IP	OwnIP
11000000	W$1VVV G	W$1SSS	W$1OOO	W$1WWW	10.12.34.56	10.78.90.13