Lecture No.19
Huffman Encoding

CC-213 Data Structures
Department of Computer Science
University of the Punjab

Slides modified very slightly from the late Dr. Sohail Aslam's lectures at VU

Other Uses of Binary Trees

Huffman Encoding

Huffman Encoding

- Data compression plays a significant role in computer networks.
- To transmit data to its destination faster, it is necessary to either increase the data rate of the transmission media or to simply send less data.
- Improvements with regard to the transmission media has led to increase in the rate.
- The other options is to send less data by means of data compression.
- Compression methods are used for text, images, voice and other types of data (space probes).

Huffman Encoding

- Huffman code is method for the compression for standard text documents.
- It makes use of a binary tree to develop codes of varying lengths for the letters used in the original message.
- Huffman code is also part of the JPEG image compression scheme.
- The algorithm was introduced by David Huffman in 1952 as part of a course assignment at MIT.

Huffman Encoding

- To understand Huffman encoding, it is best to use a simple example.
- Encoding the 32-character phrase: "*traversing threaded binary trees*",
- If we send the phrase as a message in a network using standard 8-bit ASCII codes, we would have to send 8*32= 256 bits.
- Using the Huffman algorithm, we can send the message with only 116 bits.

Huffman Encoding

- List all the letters used, including the "space" character, along with the frequency with which they occur in the message.
- Consider each of these (character,frequency) pairs to be nodes; they are actually leaf nodes, as we will see.
- Pick the two nodes with the lowest frequency, and if there is a tie, pick randomly amongst those with equal frequencies.

Huffman Encoding

- Make a new node out of these two, and make the two nodes its children.
- This new node is assigned the sum of the frequencies of its children.
- Continue the process of combining the two nodes of lowest frequency until only one node, the root, remains.

Huffman Encoding

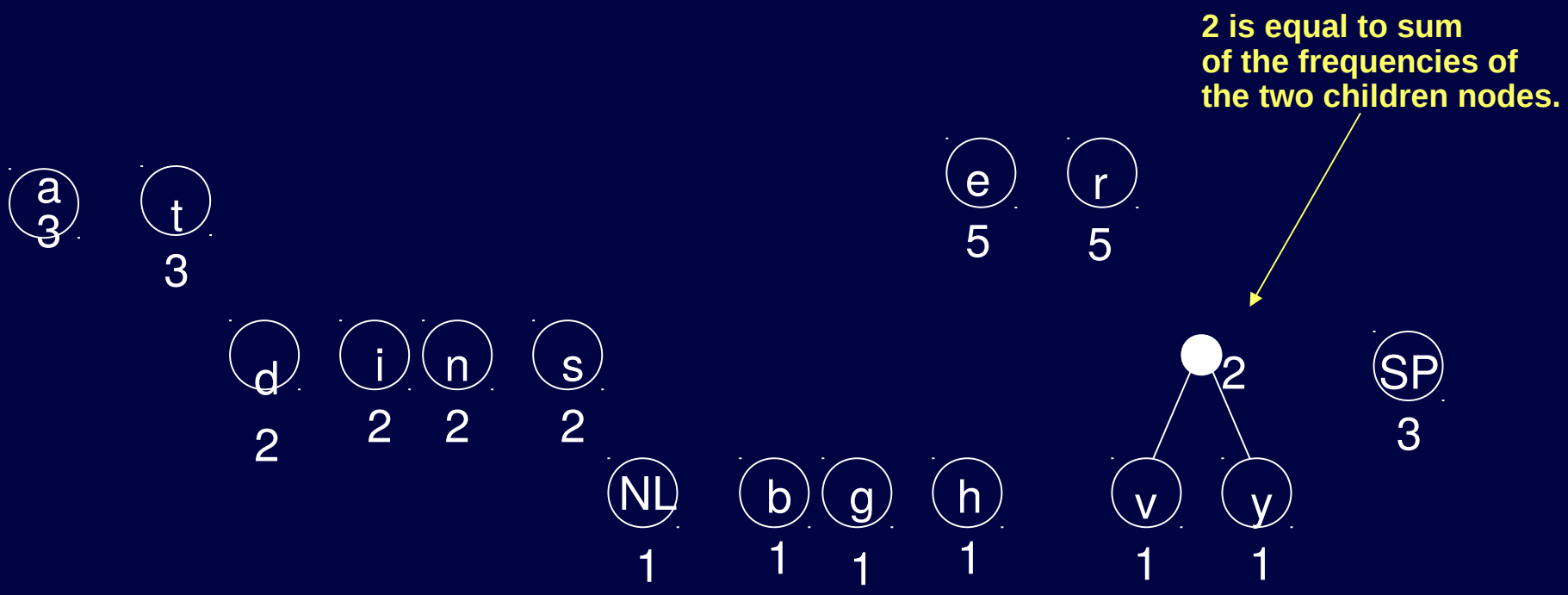
Original text:

traversing threaded binary trees

size: 33 characters (space and newline)

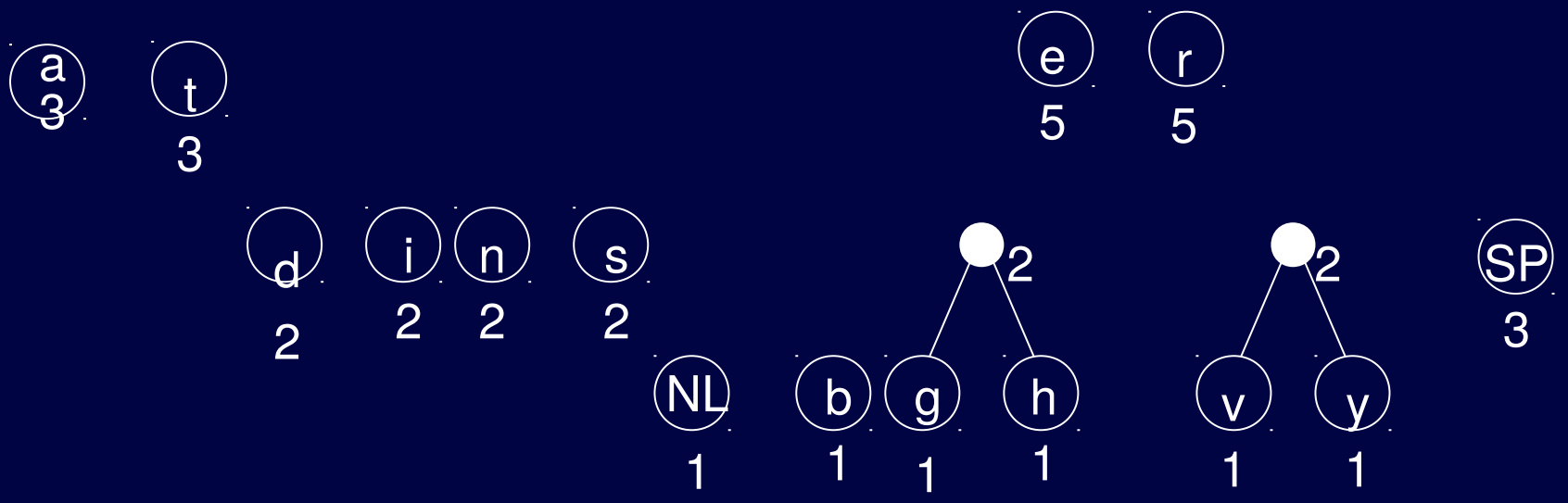
NL : 1	i : 2
SP : 3	n : 2
a : 3	r : 5
b : 1	s : 2
d : 2	t : 3
e : 5	v : 1
g : 1	y : 1
h : 1	

Huffman Encoding

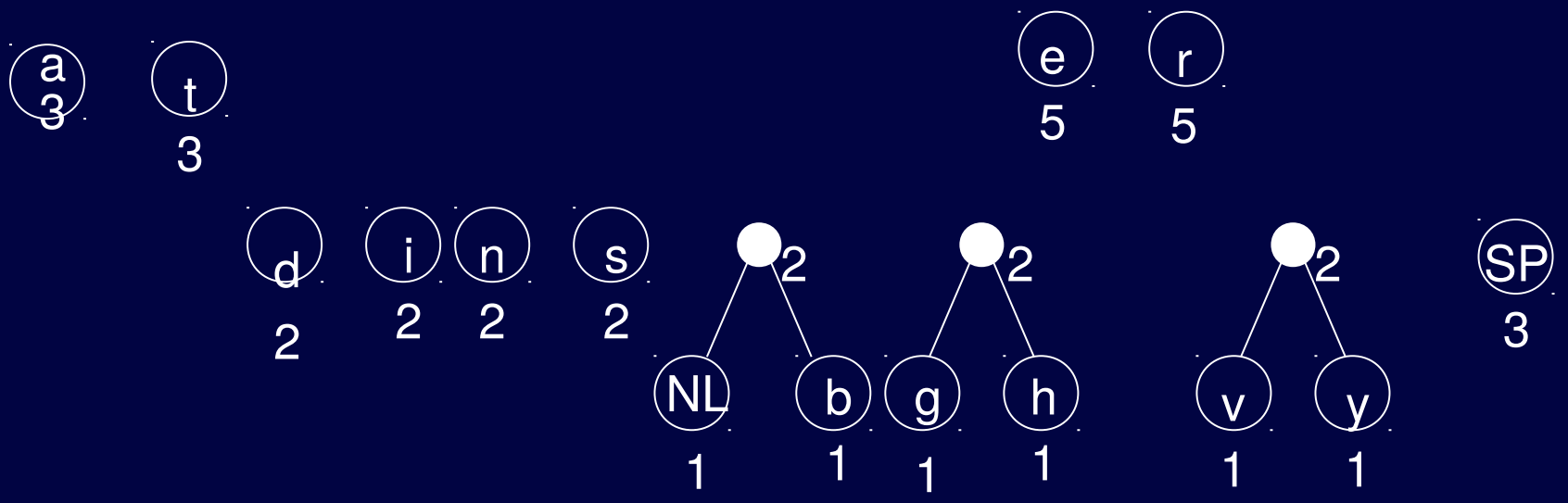


Huffman Encoding

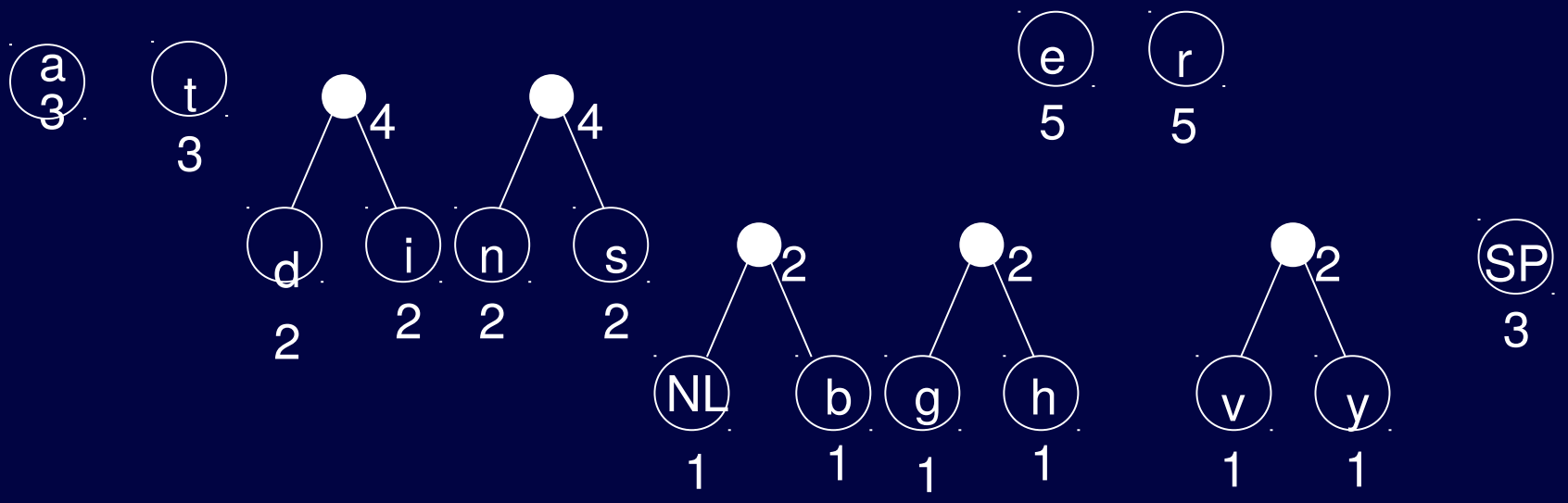
There a number of ways to combine nodes. We have chosen just one such way.



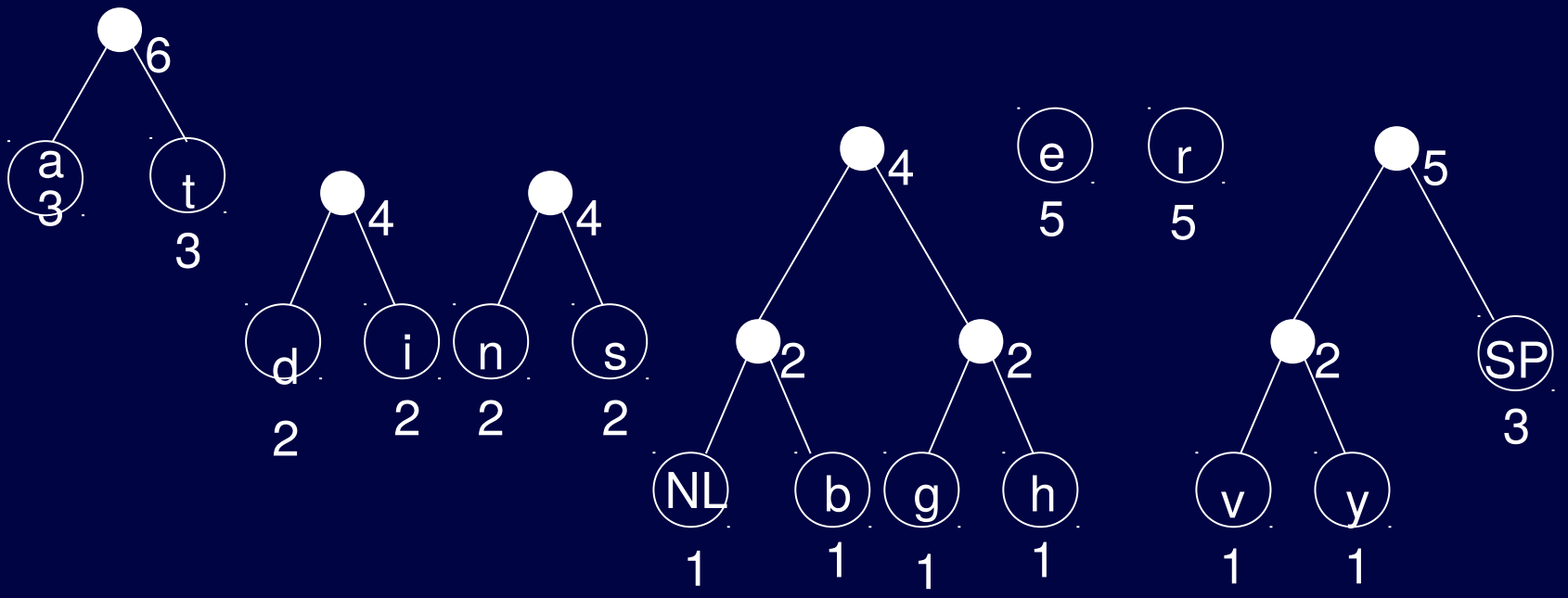
Huffman Encoding



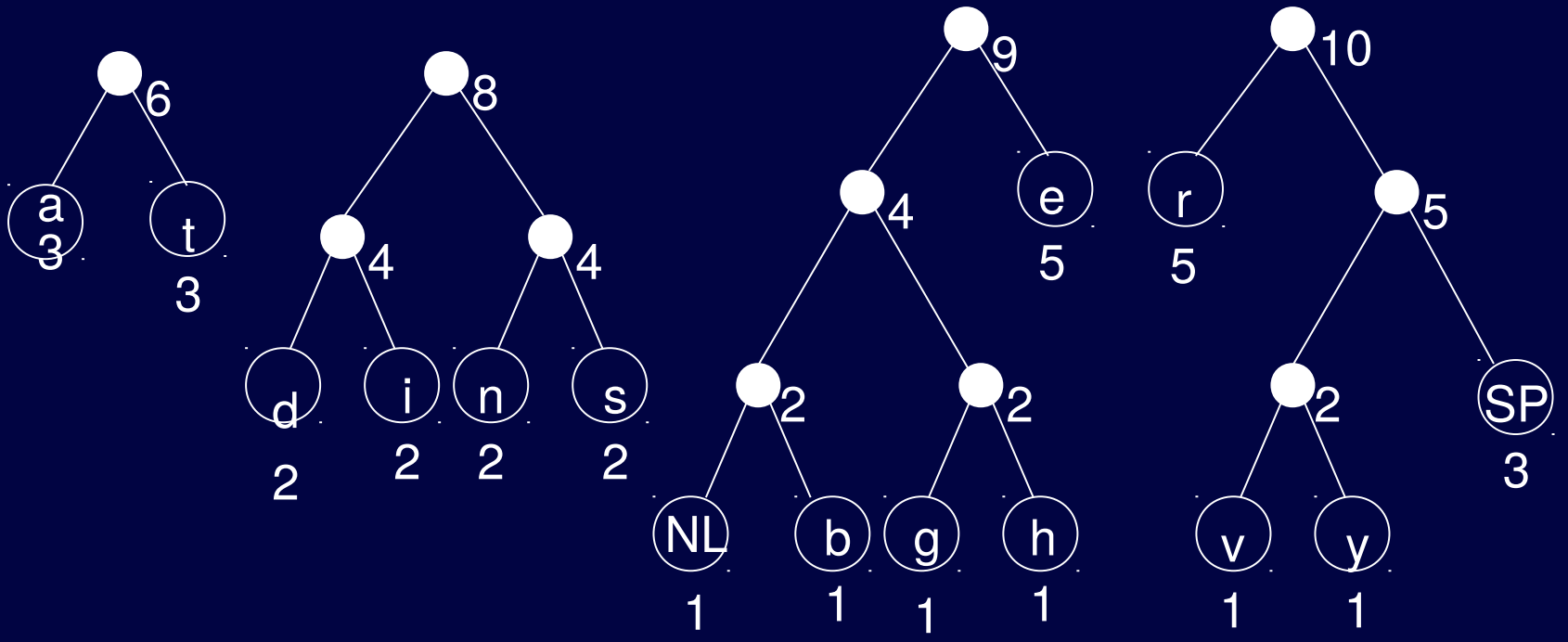
Huffman Encoding



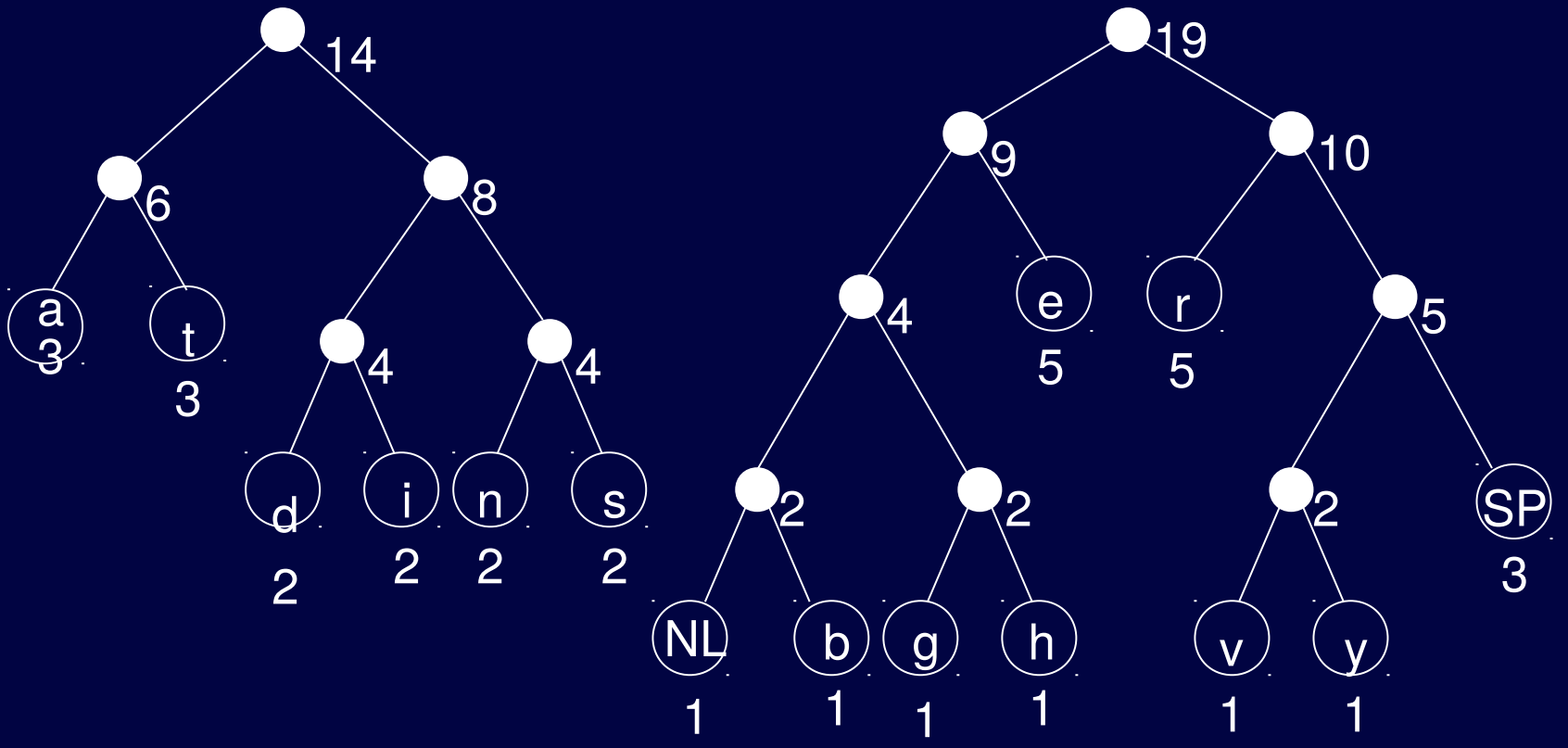
Huffman Encoding



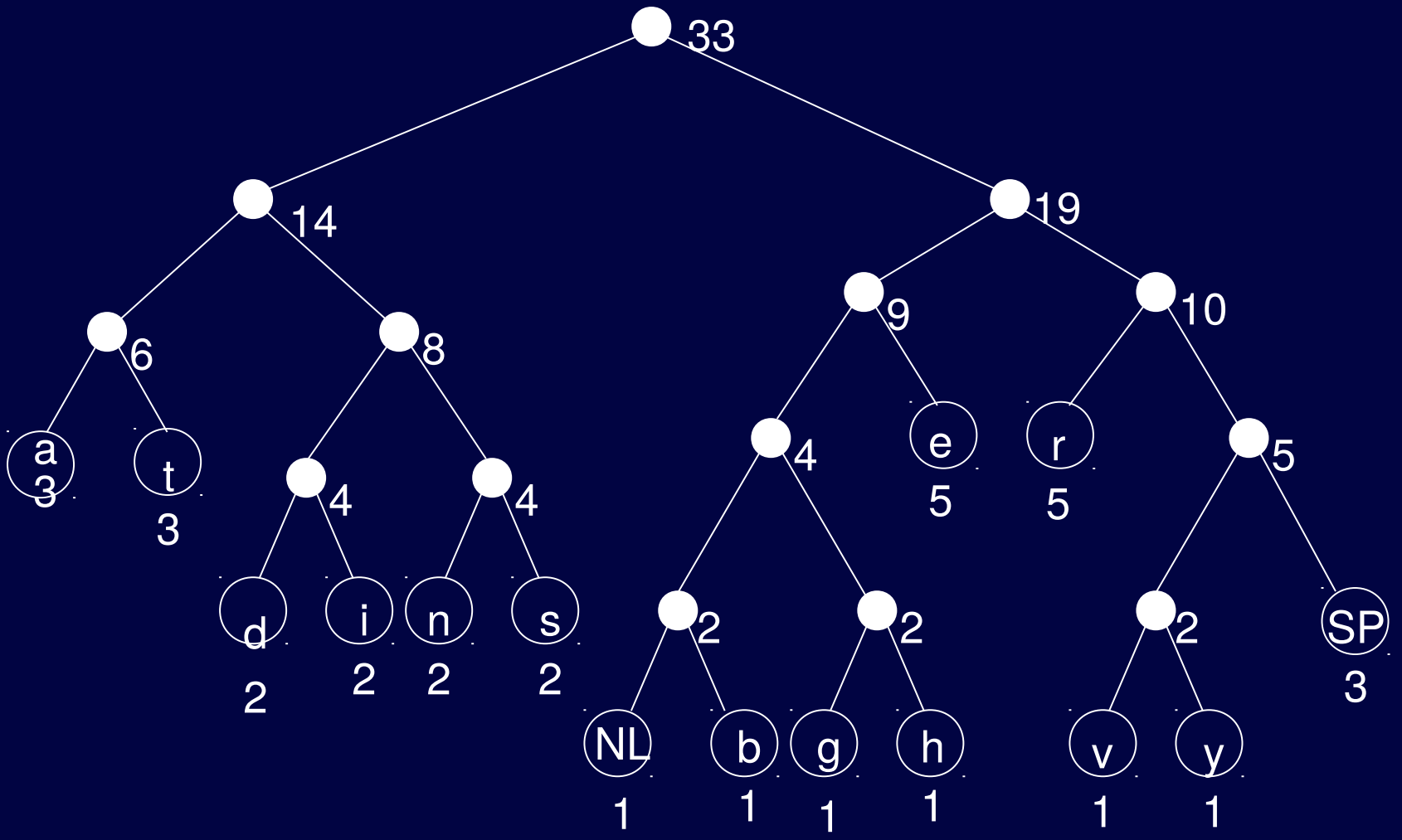
Huffman Encoding



Huffman Encoding



Huffman Encoding



Huffman Encoding

- Huffman code is method for the compression for standard text documents.
- It makes use of a binary tree to develop codes of varying lengths for the letters used in the original message.
- Huffman code is also part of the JPEG image compression scheme.
- The algorithm was introduced by David Huffman in 1952 as part of a course assignment at MIT.

Huffman Encoding

- To understand Huffman encoding, it is best to use a simple example.
- Encoding the 32-character phrase: "*traversing threaded binary trees*",
- If we send the phrase as a message in a network using standard 8-bit ASCII codes, we would have to send 8*32= 256 bits.
- Using the Huffman algorithm, we can send the message with only 116 bits.

Huffman Encoding

- List all the letters used, including the "space" character, along with the frequency with which they occur in the message.
- Consider each of these (character,frequency) pairs to be nodes; they are actually leaf nodes, as we will see.
- Pick the two nodes with the lowest frequency, and if there is a tie, pick randomly amongst those with equal frequencies.

Huffman Encoding

- Make a new node out of these two, and make the two nodes its children.
- This new node is assigned the sum of the frequencies of its children.
- Continue the process of combining the two nodes of lowest frequency until only one node, the root, remains.

Huffman Encoding

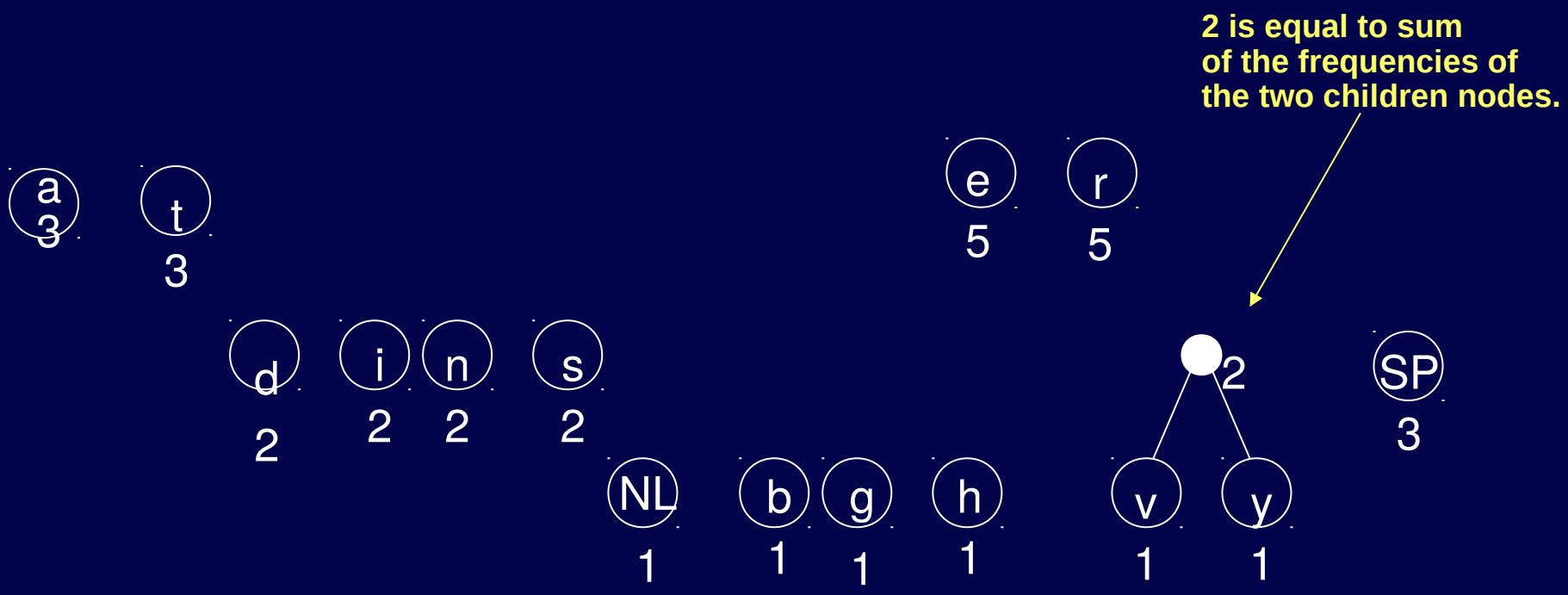
Original text:

traversing threaded binary trees

size: 33 characters (space and newline)

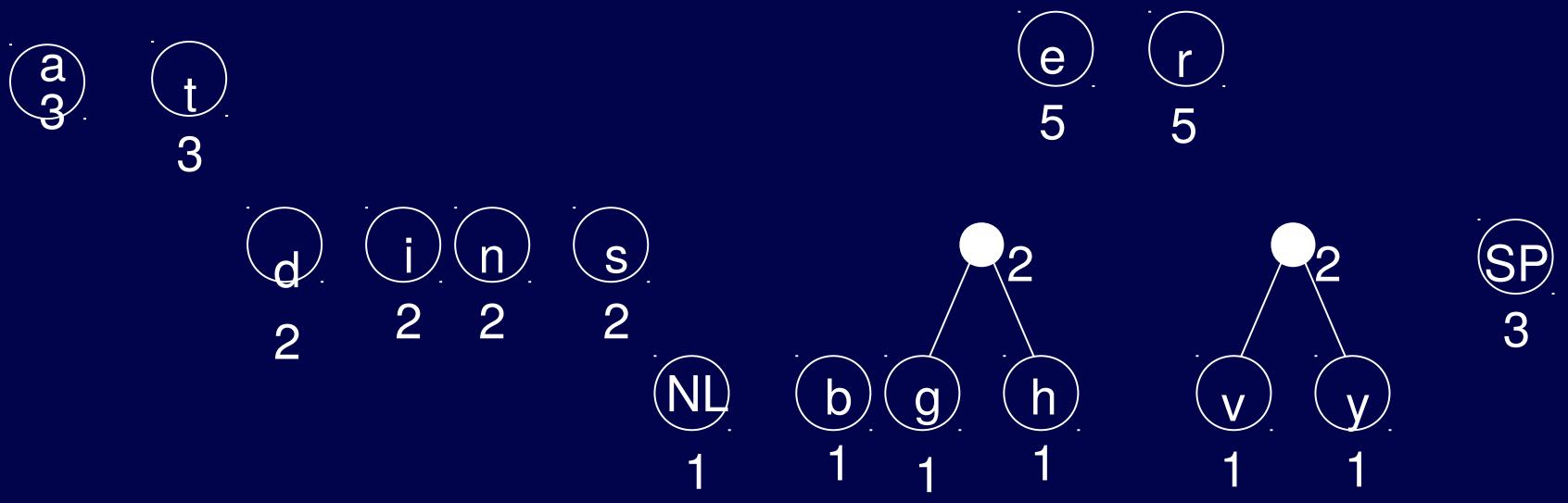
NL : 1	i : 2
SP : 3	n : 2
a : 3	r : 5
b : 1	s : 2
d : 2	t : 3
e : 5	v : 1
g : 1	y : 1
h : 1	

Huffman Encoding

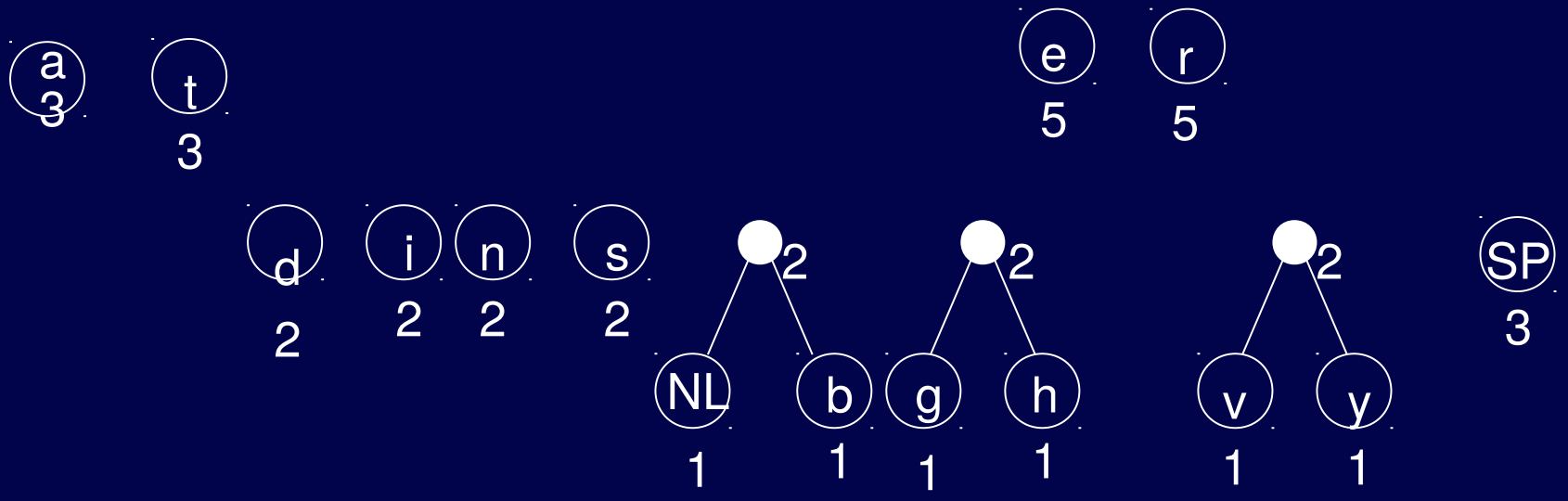


Huffman Encoding

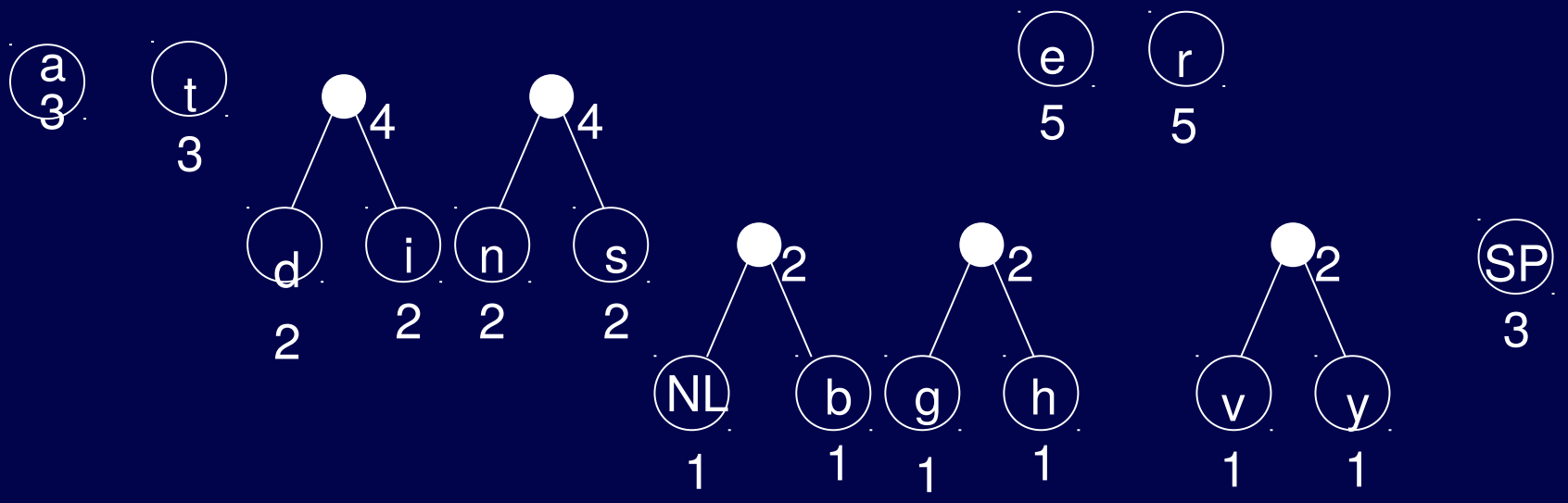
There a number of ways to combine nodes. We have chosen just one such way.



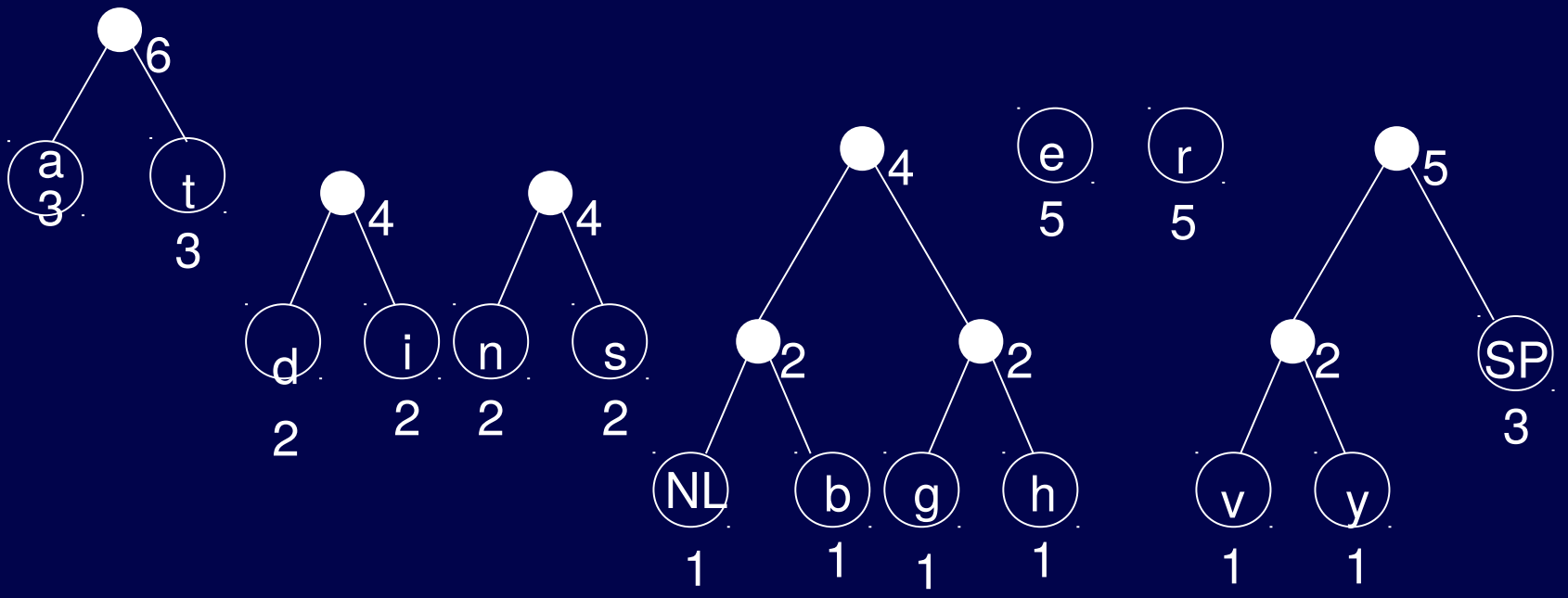
Huffman Encoding



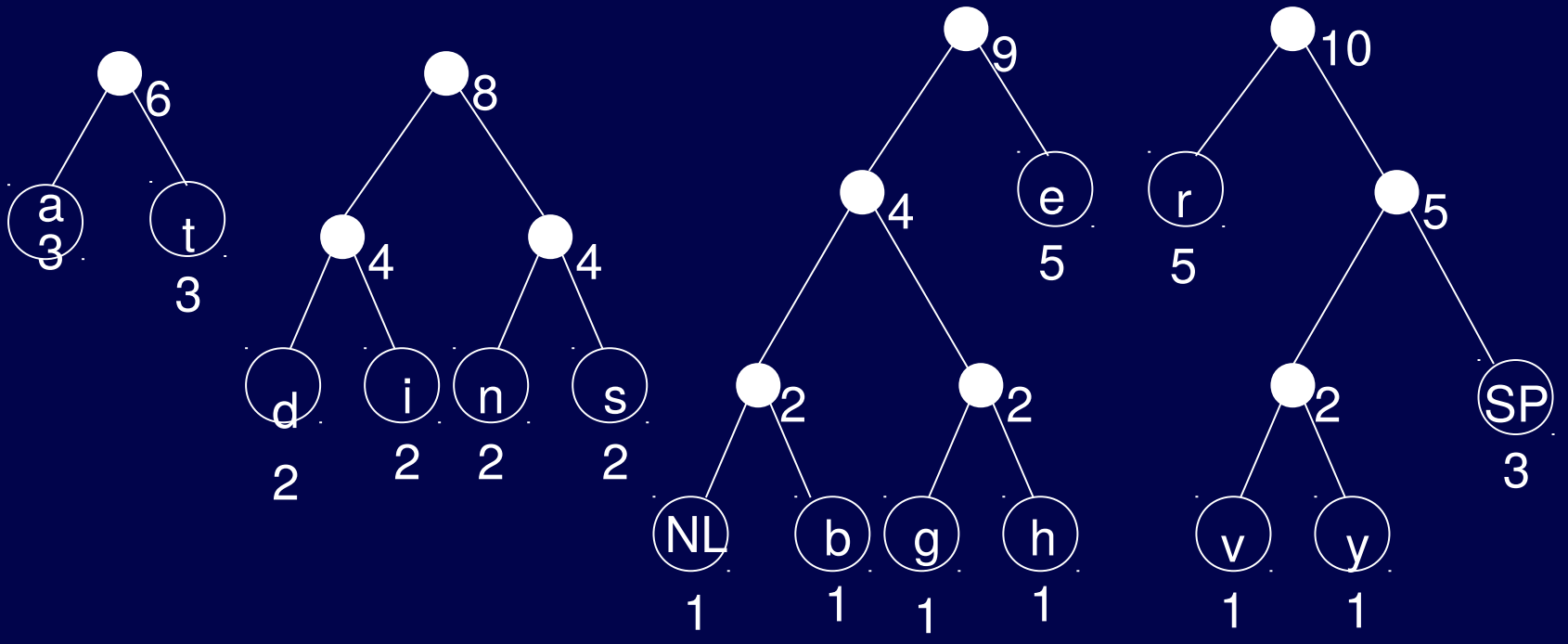
Huffman Encoding



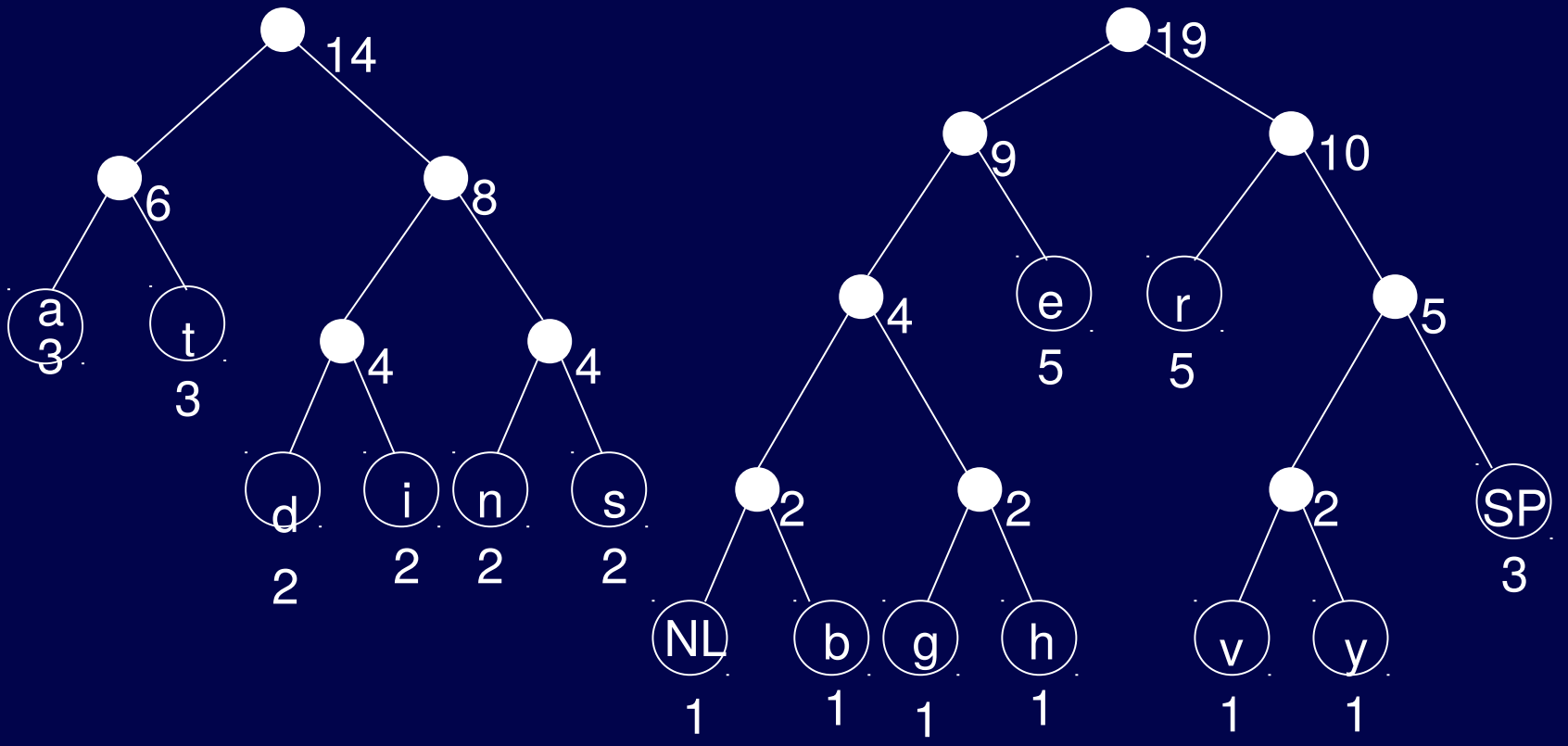
Huffman Encoding



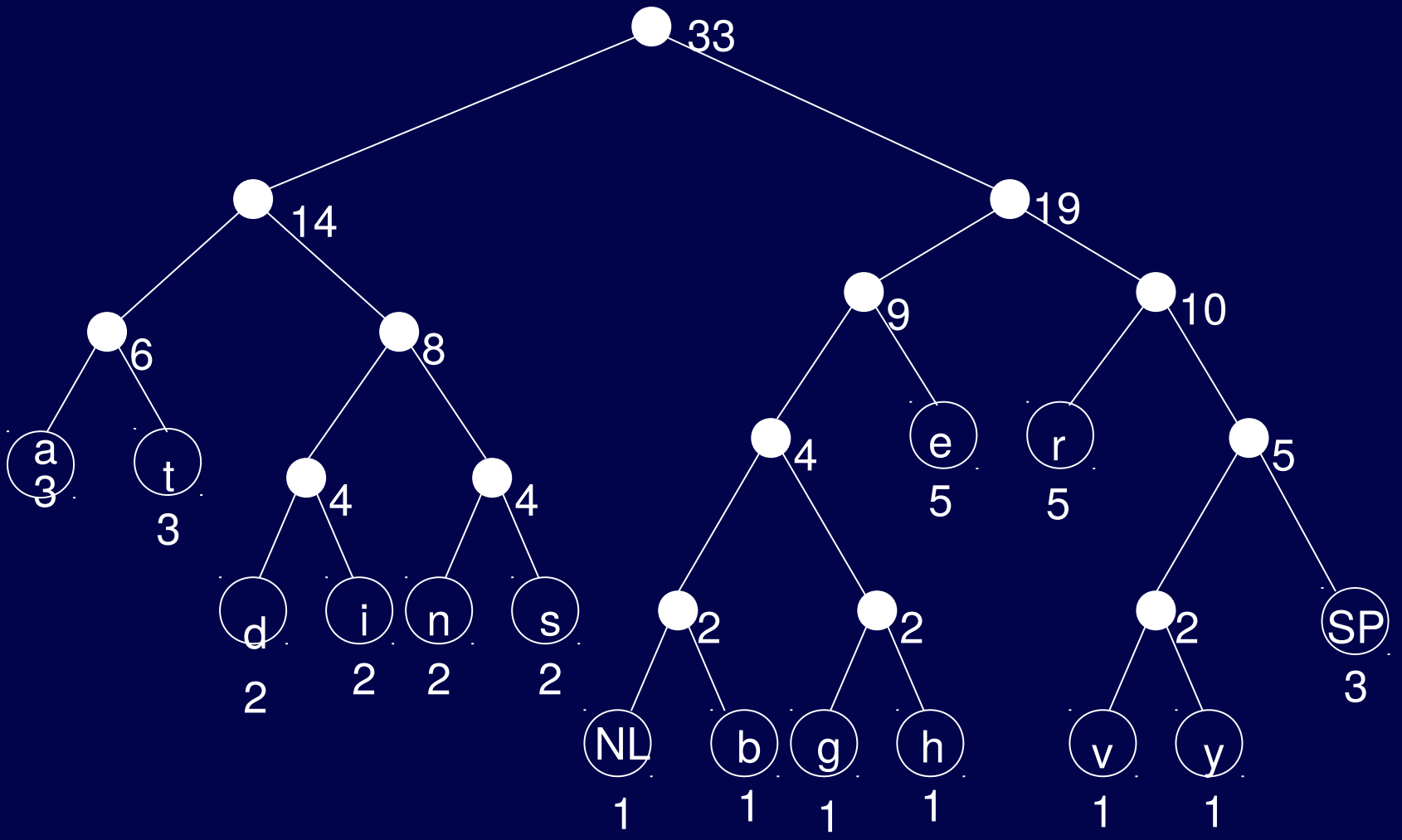
Huffman Encoding



Huffman Encoding



Huffman Encoding



Huffman Encoding

- List all the letters used, including the "space" character, along with the frequency with which they occur in the message.
- Consider each of these (character,frequency) pairs to be nodes; they are actually leaf nodes, as we will see.
- Pick the two nodes with the lowest frequency, and if there is a tie, pick randomly amongst those with equal frequencies.

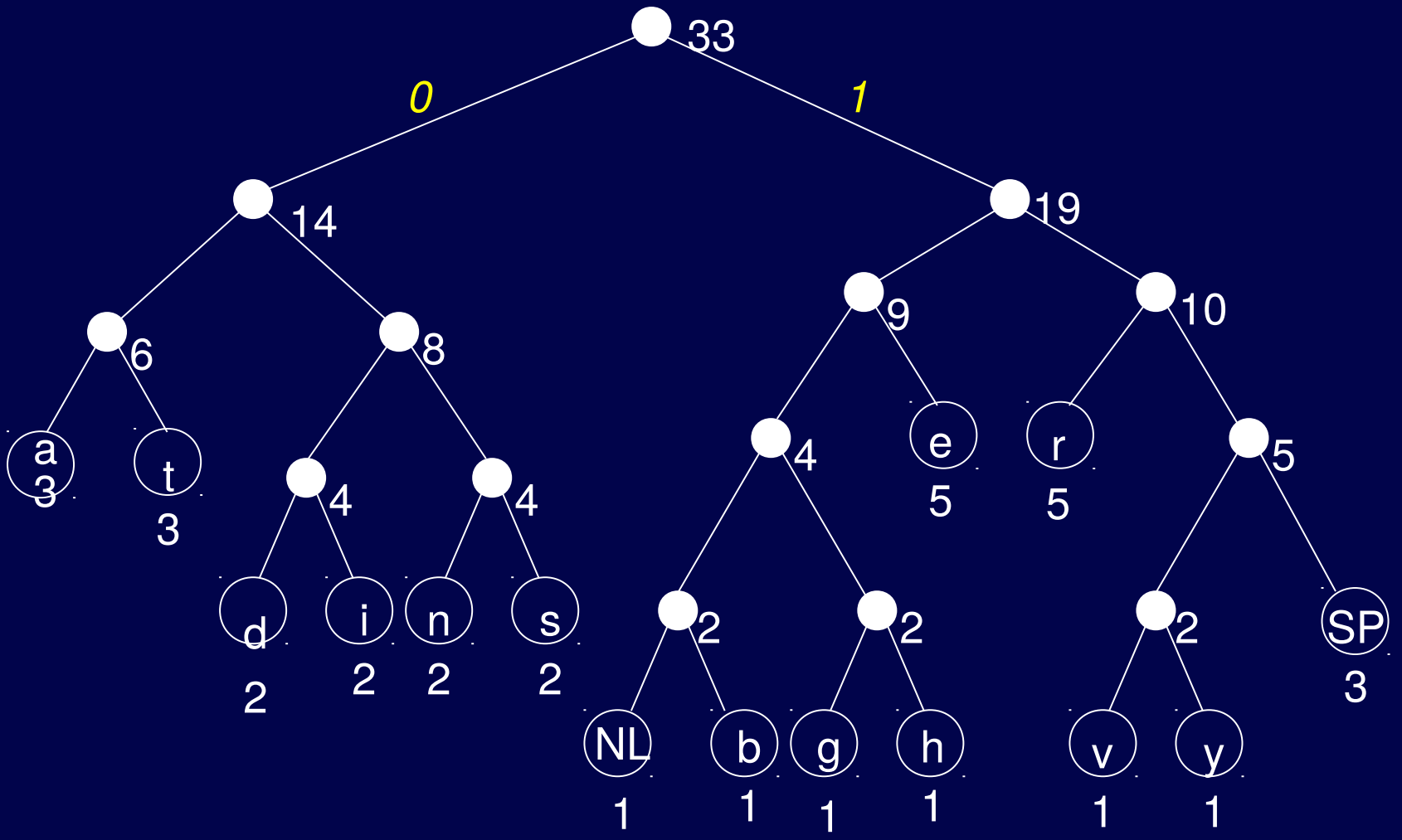
Huffman Encoding

- Make a new node out of these two, and make the two nodes its children.
- This new node is assigned the sum of the frequencies of its children.
- Continue the process of combining the two nodes of lowest frequency until only one node, the root, remains.

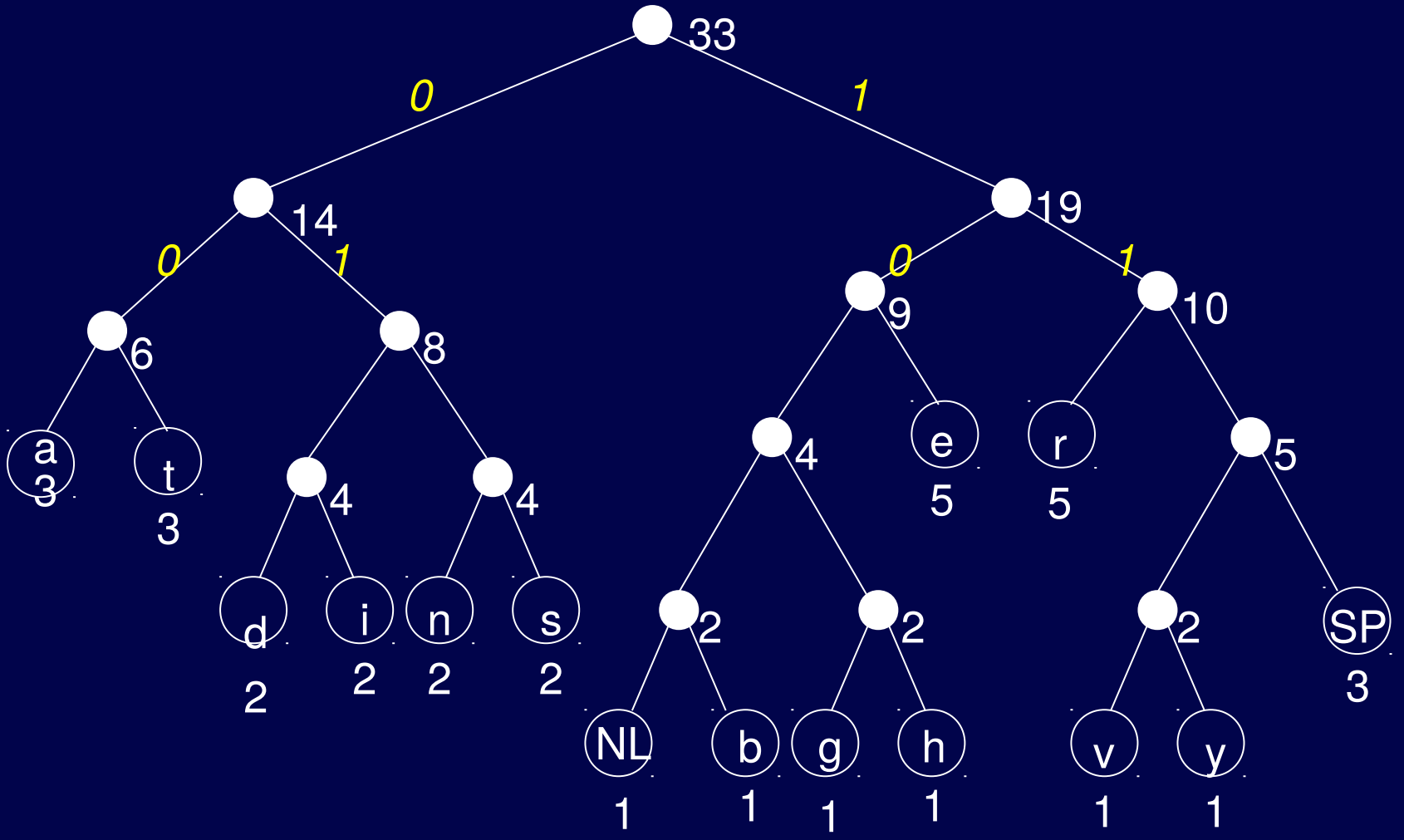
Huffman Encoding

- Start at the root. Assign 0 to left branch and 1 to the right branch.
- Repeat the process down the left and right subtrees.
- To get the code for a character, traverse the tree from the root to the character leaf node and read off the 0 and 1 along the path.

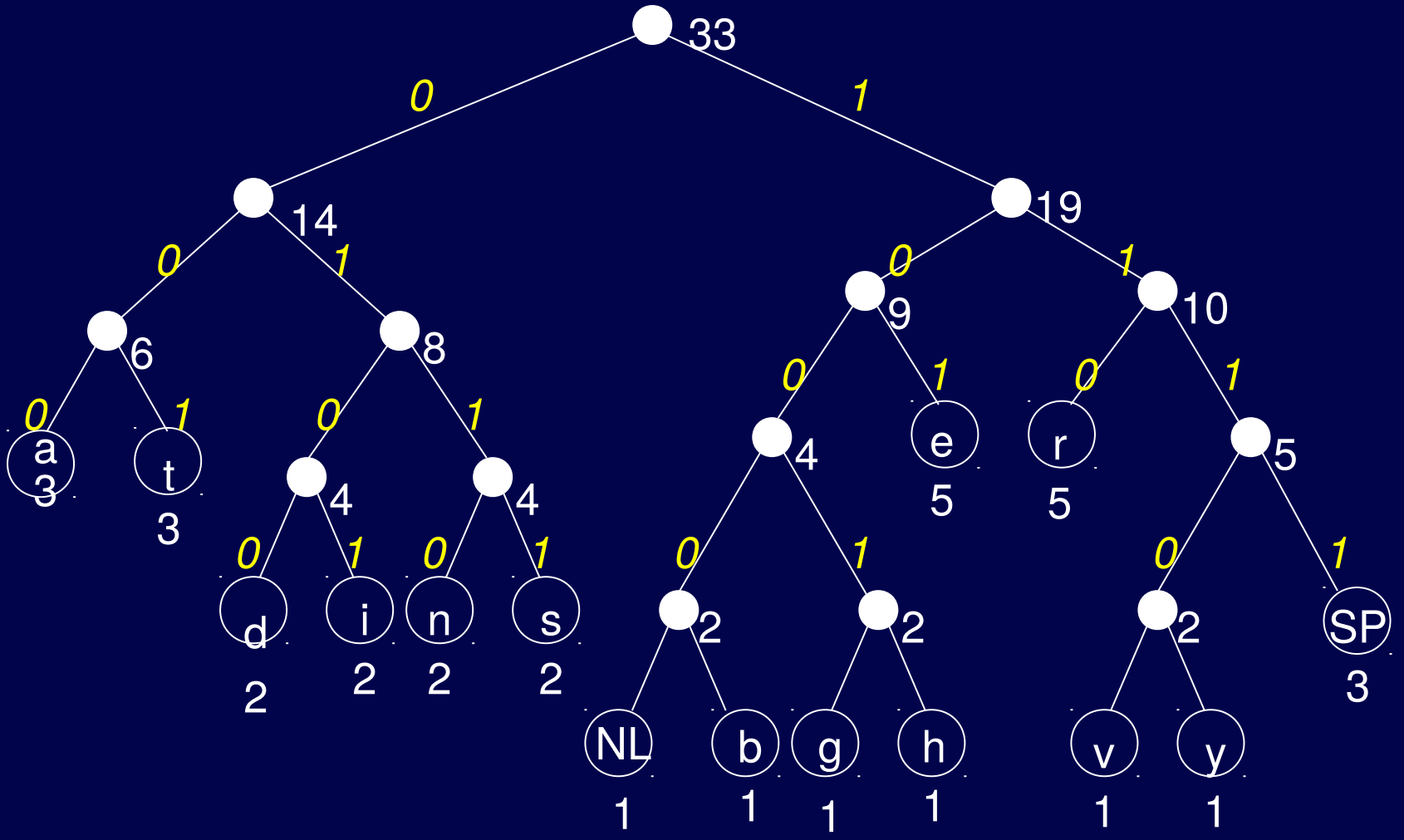
Huffman Encoding



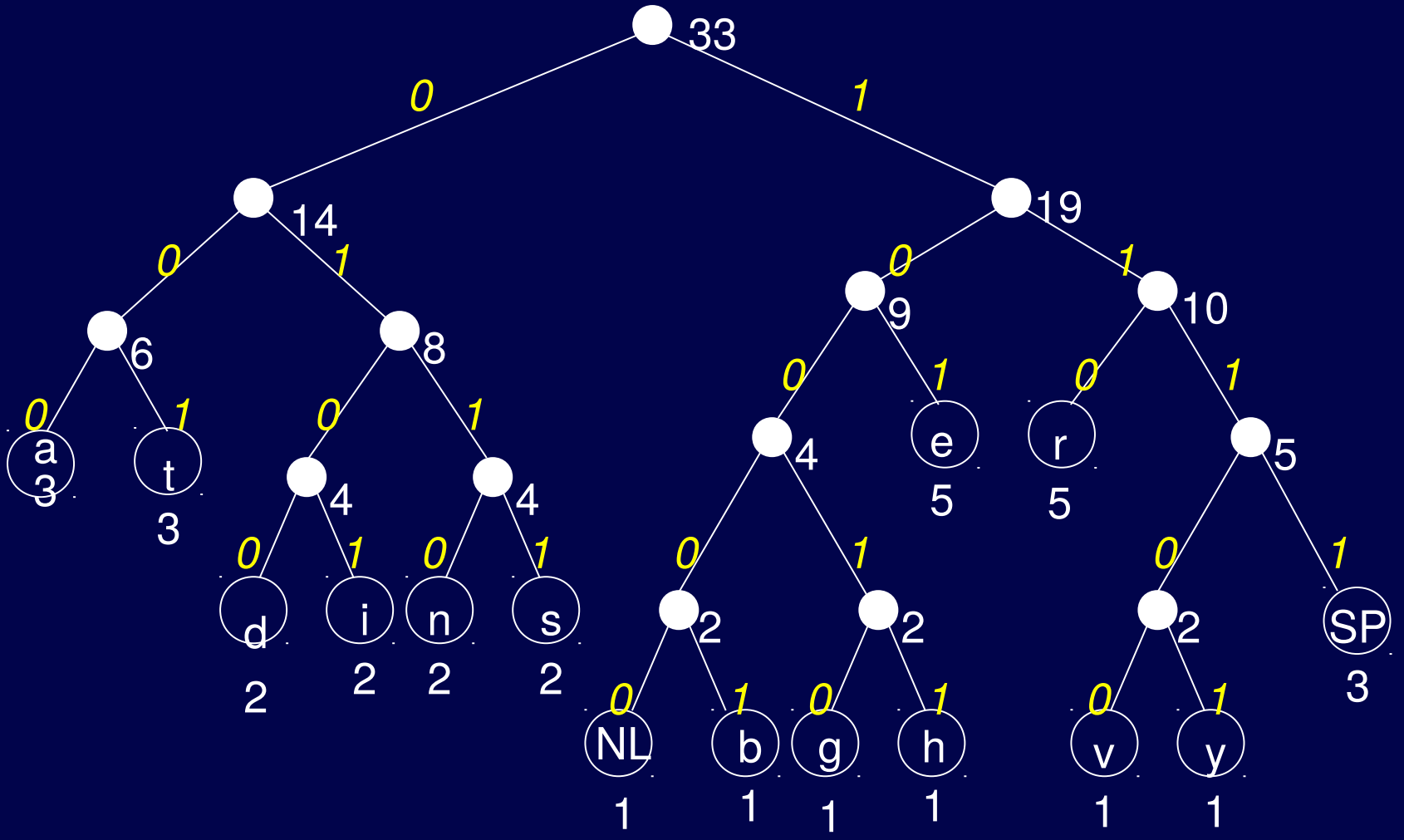
Huffman Encoding



Huffman Encoding



Huffman Encoding



Huffman Encoding

Huffman character codes

NL	⇨	10000
SP	⇨	1111
a	⇨	000
b	⇨	10001
d	⇨	0100
e	⇨	101
g	⇨	10010
h	⇨	10011
i	⇨	0101
n	⇨	0110
r	⇨	110
s	⇨	0111
t	⇨	001
v	⇨	11100
y	⇨	11101

- Notice that the code is variable length.
- Letters with higher frequencies have shorter codes.
- The tree could have been built in a number of ways; each would yielded different codes but the code would still be minimal.

Huffman Encoding

Original: *traversing threaded binary trees*

Encoded:

t r a v e

00111000011100101111001110101011010010111100110011110101000010010101001111110000101010110000110111011111001110101101110000

Huffman Encoding

Original: *traversing threaded binary trees*
With 8 bits per character, length is 264.

Encoded:
00111000011100101110011101010110100
10111100110011110101000010010101001
11110000101011000011011101111100111
010110101110000

Compressed into 122 bits, 54% reduction.