A Brief Survey on RC4 Cryptography

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***Abstract*—RC4 may be a stream cipher which was most generally accepted for its structural simplicity. it's high rate of encryption and decryption rate i.e speed and efficiency. There were several reports on RC4 algorithm vulnerabilities and further proposals on modified RC4 algorithm. In spite of of these vulnerabilities still RC4 is been utilized in TSL web connections. There were many efforts on removing weakness of RC4 like biased key , key collisions, key recovery etc , specifically from WEP ,so WPA standard was introduced to over come these vulnerabilities . WPA was again proved insecure due to TB data injection attack.researchers are performing on RC4 from past 20 years but still the attraction towards RC4 has been alive.**

***Index Terms*—RC4 , cryptography , stream cipher , algorithm , survey**

I. Introduction

RC4(Rivest Cipher 4) is additionally referred to as ARC4 or ARCFOUR meaning Alleged RC4. RC4 may be a stream cipher , which is understood for its simplicity and performance in software . RC4 became a neighborhood of encryption protocols and standards, like WEP in 1997 , in 2003 WPA was released for wireless cards , and in 1995 SSL and its successor TLS in 1999 ,TLS and SSL was a great success until it was prohibited in 2015 due to RC4 attack or cracking RC4 which was main cryptography used in SSL/TLS. RC4 was very easy to implementation on software and hardware devices. RC4 may be a symmetric encryption where single key's shared between both the parties to encrypt and decrypt the cipher [1] Secret key ciphers can be classified into 2 main branches

a.stream ciphers

b. block ciphers.RC4 may be a Stream cipher which suggests it encryption takes palace bit by bit where as in block ciphers it the encryption will happen during a fixed size block. The strength of the stream cipher depends on the random key stream generated which is then xor-ed with the plain text.

II. Algorithm

RC4 algorithm has 2 main components KSA(Key-scheduling algorithm) and PRGA(Pseudo-random generation algorithm) . the key key's passed though KSA and PRGA the output is bitwise xored with plaintext. it's almost like just one occasion pad expect that the pseudorandom number generated by PRGA is employed instead of prepared streams.

KSA is employed for initializing the S array , the output is given to PRGA.

KSA algorithm

```
for i from 0 to 255
    S[i] := i
endfor
j := 0
for i from 0 to 255
    j := (j + S[i] + key[i mod keylength]) mod 256
    swap values of S[i] and S[j]
endfor
```

For as many iterations as are needed, the PRGA modifies the state and outputs a byte of the keystream. In each iteration, the PRGA.

PRGA algorithm

```
i := 0
j := 0
while GeneratingOutput:
    i := (i + 1) mod 256
    j := (j + S[i]) mod 256
    swap values of S[i] and S[j]
    K := S[(S[i] + S[j]) mod 256]
    output K
endwhile
```

the output K stream is xored with the plaintext to encrypt the info , or it's xored with ciphertext to decrypt the info

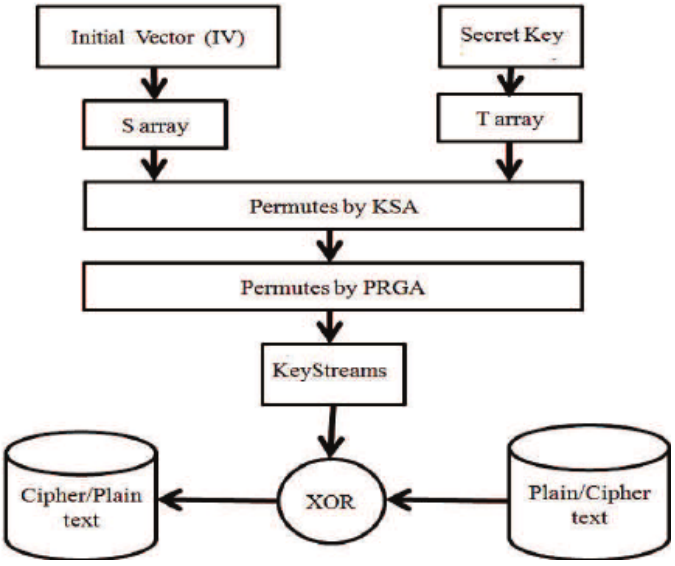


Fig. 1. RC4 flow diagram

III. MODIFICATION APPROACHES

PSEUDO CODE I

KSA OF IMPROVED RC4 PROPOSED BY JIAN XIE ET AL:[2].

```
for i= (0 to N-1)
{
   S1[i]=i;
   S2[i]=i;
}
j1=j2=0;
for i=0 to N-1
{
   j1=( j1+S1[i]+k1[i]) mod N;
   swap(S1[i], S1[j]);
   j2=( j2+S2[i]+k2[i]) mod N;
   swap(S2 [i], S2[j]);
}
```

PSEUDO CODE II

PRGA OF IMPROVED RC4 PROPOSED BY JIAN XIE ET AL:[2].

```
i=j1=j2=0;
Loop
{
i=i+1;
   j1= j1+S1[i];
   swap(S1[i], S1[j]);
   j2= j2+S2[i];
   swap(S2[i], S2[j]);
   Output= S1 [(S1 [i]+ S1[j]) mod N];
   Output= S2[(S2 [i]+ S2[j]) mod N];
   swap(S1[S2[j1]], S1[S2[j2]]);
   swap(S2[S1[j1]], S2[S1[j2]]);
}
```

PSEUDO CODE III

KSA OF THE MODIFIED RC4, SAME AS RC4

```
for i = 0 to 255
   S[i] = i;
j=0

for i = 0 to 255
   j = (j+S[i]+K[i mod l]) mod 256;
   swap S[i] and S[j];
```

PSEUDO CODE IV

PRGA OF THE MODIFIED RC4

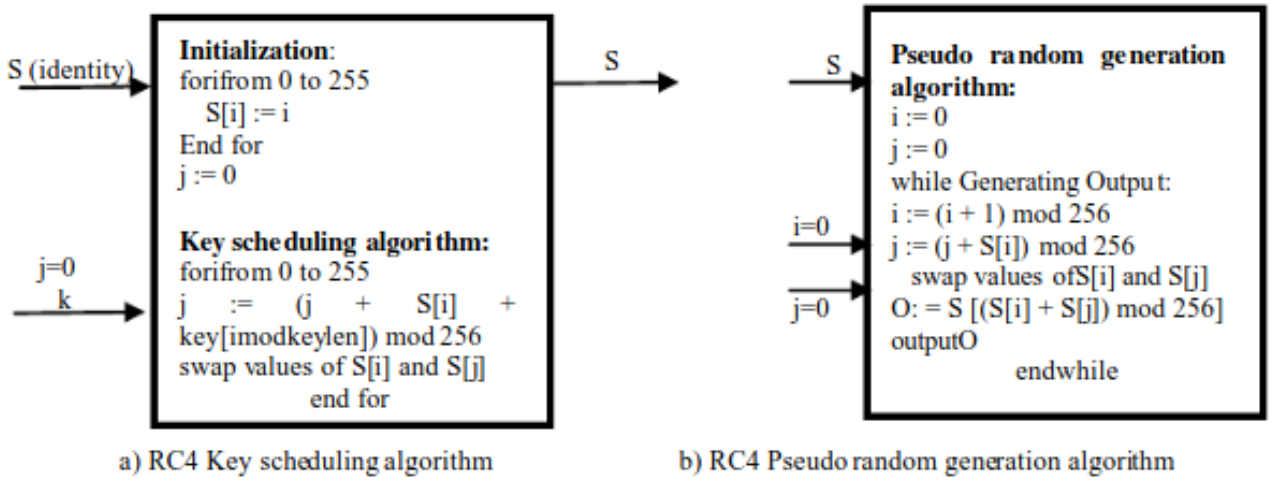
```
i = 0, j=0;

for x = 0 to (M-1)
{
   i = (i+1) mod 256;
   j = (j+S[i]) mod 256;
   swap S[i] and S[j];
   GeneratedKey = S[ (S[i] + S[j]) mod
256] ;
   Output = M[x] XOR GeneratedKey XOR j;
}
```

Many more modification on RC4 are made in decades to improve security as well as speed .

IV. SECURITY ANALYSIS

- RC4 is mainly used in WLAN security protocols because of it performance and low computation power need. Wired equivalent privacy (WEP) is the primary



a) RC4 Key scheduling algorithm b) RC4 Pseudo random generation algorithm

Fig. 2. RC4

security protocol used for Wi -Fi security in IEEE 802.11 LANs and is based on RC4 encryption algorithm. due to the amount of attacks on WEP such as; related key attacks[3], Fluhrer, Mantin and Shamir attack (FMS)[4], Korek practical attacks[5], Mantin attack on RC4 [6] and WEP,and many more therefore WEP was announced as an insecure protocol. WPA was more secure by defended against many attacks in WEP.

- WPA has again announced to be a weak protocol due to TB data injection attacks[7], and SVV attacks[8]]. new protocol WPA2 was announced which uses AES (type of symmetric cipher called Advance encryption standard which is a type of block cipher) as an encryption algorithm instead of RC4. Even Though WPA2 may be a secure protocol, removing many vulnerabilities of WEP. hardware based applications which uses WEP and WPA with RC4 were cost effective.
- Further a replacement protocol WPA2 was proposed by the WiFi alliance which uses AES block cipher as an standard encryption algorithm instead of RC4. Though WPA2 could also be a secure protocol, removing many vulnerabilities of WEP and WPA but its hardware based applications are not cost effective as compare to WEP and WPA where RC4 cryptography algorithm is used as a basis.
- RC4 is additionally widely used and accepted in web security. it's utilized in Transport layer security (TLS) /SSL to supply security over the web . The RC4 is understood to the simplest choice for TLS/SSL because it can mitigate many attacks on the protocol. However recently in 2013 and 2014, a replacement security attack[9] on RC4 of Although there has been many successful security breaches within the protocols using RC4, but the striking combination of style elegance and robustness of RC4 has made it most widely accepted protocol for last 20 years .

V. Application

RC4 was widely utilized in WLAN connection in WEP and WPA . WPA2 uses AES for better security . RC4 was been utilized in TLS/SSL before 2015 which is not any more utilized in web security. versions of RC4 is employed in bluetooth , radios and lots of more small devices which has low computation power but yet security is vital There are many variant of RC4 like RC4A proposed by Bart Preneel and Souradyuti Paul [10]
Variably Modified Permutation Composition (VMPC) [11]
Spritz by Rivest, Ron; Schuldt, Jacob (27 October 2014)[12].
RC4+ by Goutam Paul and Subhamoy Maitra (19 September 2008)[13]

Conclusion

In this article I even have presented a fast study of RC4 ,about is robust feature and its weaknesses . How easy it is to implement on hardware and software .I had presented a wide kinds of RC4 algorithms improving the security aspects of RC4 . it had been widely utilized in wireless communication(like WEP and WPA) and web security like TLS/SSL until it had been declared to be insecure .
In spite of all the improvements / developments reported within the literature, there are still many open research issues and challenges related to searches of more key collisions in key stream, biases, and key recovery attack on WPA .The conclusion is there's still research happening , on RC4 to

Table 2. Cryptanalysis on RC4 stream cipher

Year	Weak keys* and key recovery from state	Key recovery from key stream	State recovery attack	Biases and distinguishers
1995	-Roos [23] -Wagner weak keys[24]	-	-	-Roos biases[23]
1996	-	-	-	-Glimpse bias[20]
1997	-	-	-	-Golic long term bias[29]
1998	-	-	- KMP branch and bound approach [31]	
2000	-Related key-pairs[25]	-	-Iterative probabilistic cryptanalysis[32]	-Digraph biases [30]
2001	-	FMS WEP attack[8]	-	Broadcast attack [51]
2002	-	-	-	-
2003	-	-	State part known attack[32]	
2004	-	Korek WEP attack[9]	-	
2005	-	Mantin WEP attack[10]	-	
2006	-	Klein WEP attack[11]	-	-
2007	- short related keys attack	-TWP WEP attack[12] -VV WEP attack[13]	Hill climb search attack[55]	
2008	-Difference equations -key byte -bit by bit approach attack	-	-generative pattern[34] -iterative probabilistic attack[35]	Maitra and Paul conditional Bias[37]
2009	-key collision attacks -bidirectional search attacks	-TB WEP and WPA attacks[14]	-	-
2010		SVV WEP attack[15]	-	SVV biases in key and state variables[17]
2011	-New key collisions	SVV WEP and WPA attack[16]	-	-keylength biases[51]
2012	-	SVV WEP and WPA attack[11]	-	
2013	-Near colliding keys	SSVV passive attack on WEP[18]	-	-TLS and WPA attack[38]
2014	-	-	-	-biased bytes [22]

Fig. 3. list of known weakness of RC4

make it more efficient and robust encryption algorithm.

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