GSM

Gerhard P. Fettweis – Vodafone Chair Professor

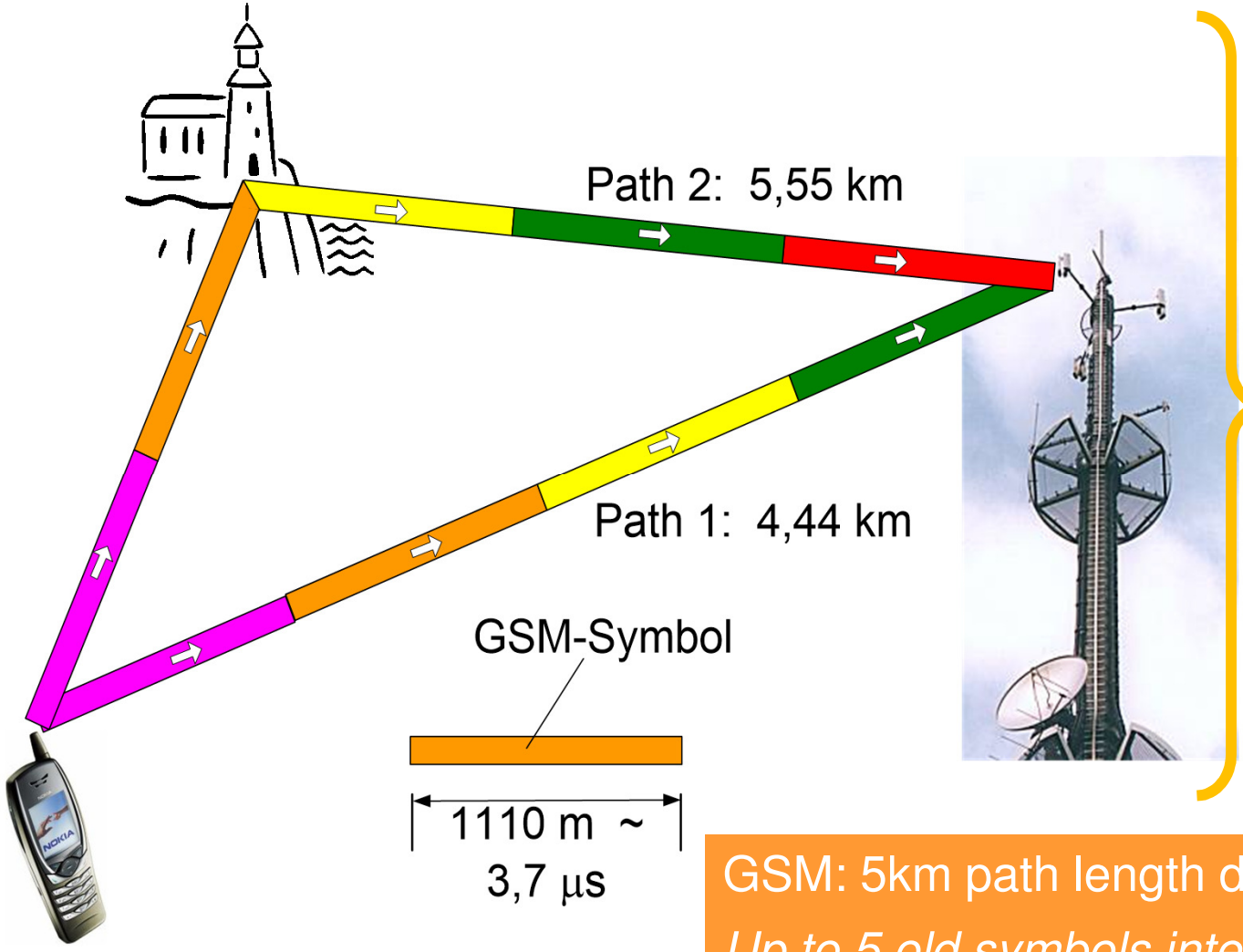
ICC 2013 – Budapest

G. Fettweis
A 5G Wireless Communications Vision , 2012-12-15, Microwave Journal
www.microwavejournal.com/articles/print/18751-a-5g-wireless-communications-vision

Historic Cellular PHY Perspective

Coping with the **PA**
Coping with the **Channel**
Coping with **Time**
Coping with **Space**
Coping with **Frequency**

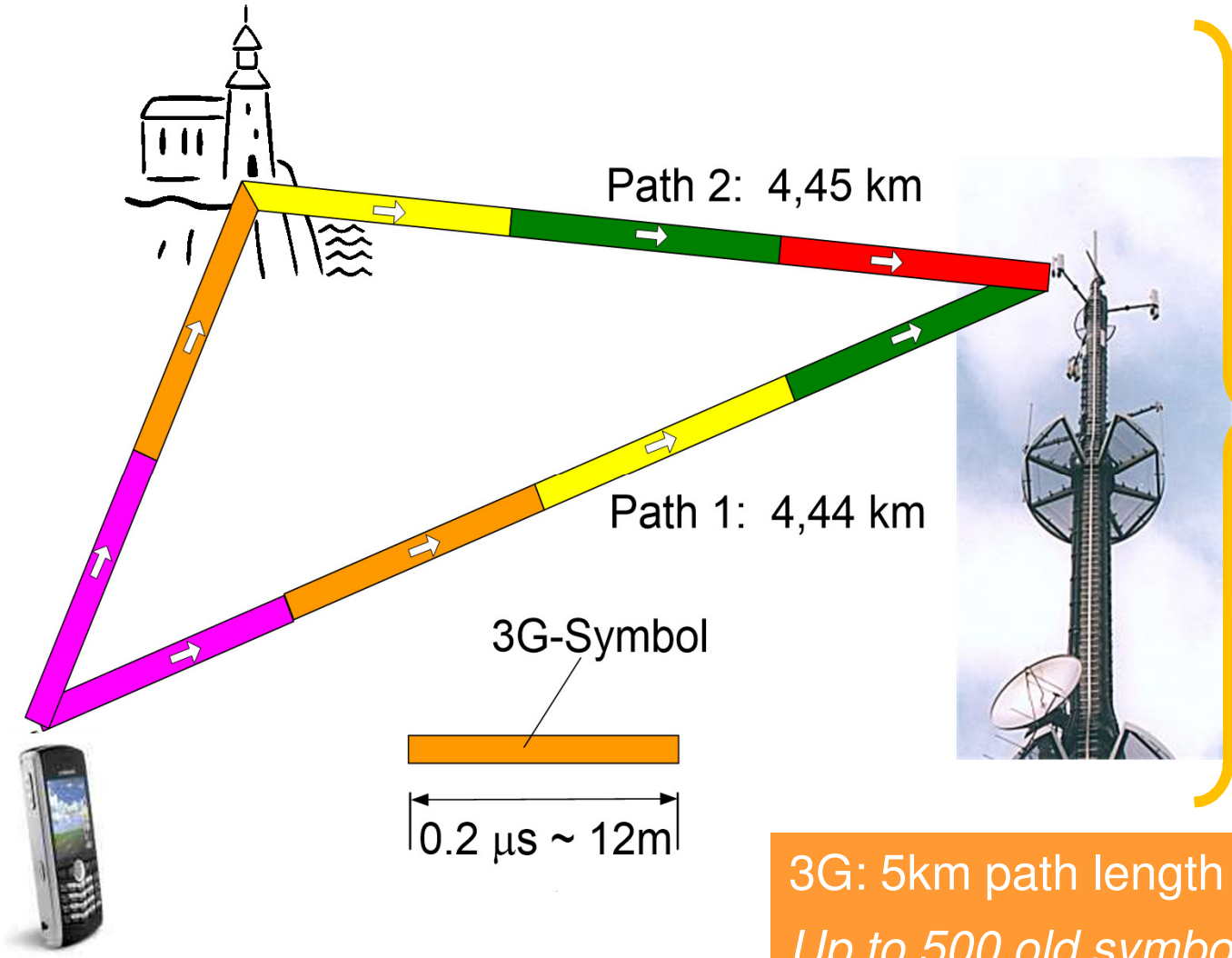
Coping with Time: Single Carrier



MLSE
Equalizer Complexity
Grows Exponentially
With Length of Echo!!

GSM: 5km path length difference *!!*
Up to 5 old symbols interfere !!

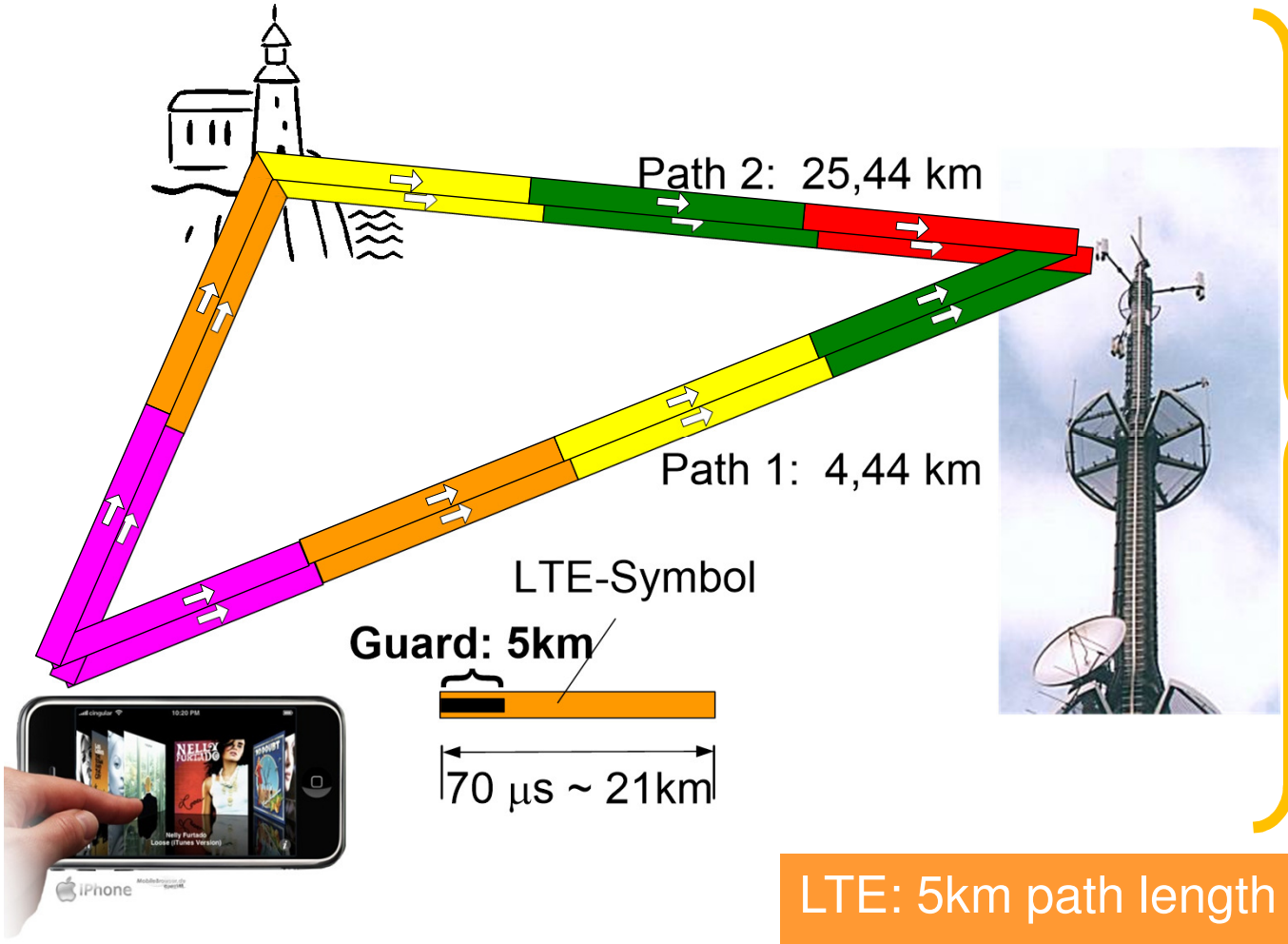
Coping With Time: Spread Spectrum



RAKE
Receiver Complexity
Grows Linearly
With # of Echoes!!

3G: 5km path length difference*!!*
Up to 500 old symbols interfere !!

Coping With Time: OFDM



OFDM Receiver Complexity Grows Logarithmically with Length of Echoes!!

LTE: 5km path length difference*!!*

ZERO old symbols interfere !!

Receiver Complexity Reduction

2G: MLSE

Equalizer Complexity
Grows Exponentially
With Length of Echoes!!

3G: RAKE

Receiver Complexity
Grows Linearly
With number of Echoes!

4G/LTE: OFDM

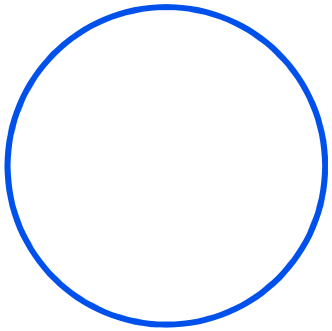
Receiver Complexity
Grows Logarithmically
With Length of Echoes!!

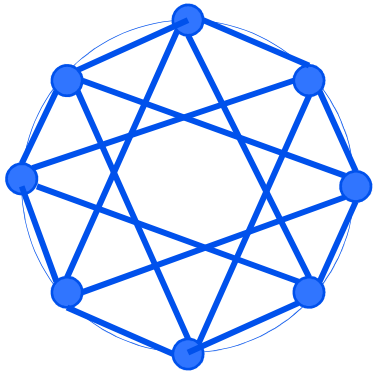
Power Amplifier

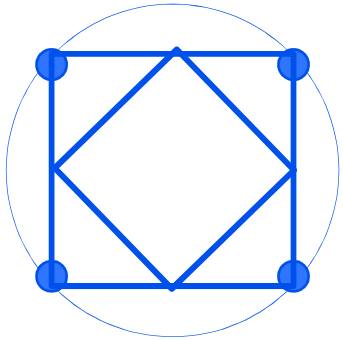
Original idea: 8W transmit power for car phones

- PAPR: Peak-to-Average Power Ratio
- PAPR determines the power amplifier required

➔GSM: GMSK Gaussian Minimum Shift Keying





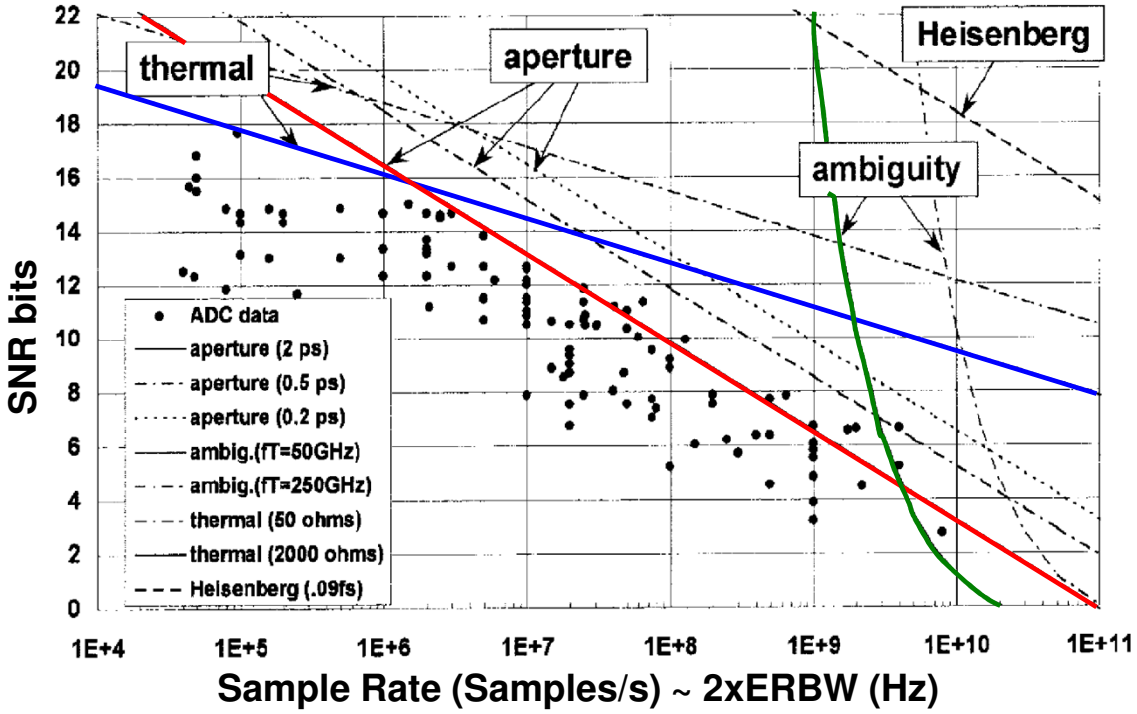


Analog to digital conversion challenge

Choose an AD interface that can be implemented

- Concerning power budget
- Die size budget (AFE chip / analog front-end)

Analysis of SNR limiting effects of (Nyquist-)ADCs



SNR performance limits due to:

- thermal noise
- aperture jitter
  - sampling time errors
- comparator ambiguity
  - quantization errors due to limited comparator speed

taken from: Walden, Robert H.: “Analog-to-Digital Converter Survey and Analysis.” IEEE JSAC-17(4), 1999.

- For an effective resolution bandwidth (ERBW) range of about 1 MHz to 1 GHz **aperture jitter** is the dominating effect that limits the SNR of high resolution wideband ADCs.
- **In 1986: 8-bit ADCs at 200kHz were ok to be integrated in silicon!**

Spectrum Limitations

Requirements

- Spectrum availability
- Coverage “guarantee”
- RF circuit technology

Solution

- ~ 900MHz

Now to Physics

A wireless channel

- Delay spread
- Doppler spread
- Coherence time
- Coherence bandwidth

Physical Channel Limitations

35km cell radius

- Timing advance of 100µs
- Delay spread <6km
- Delay spread of 20µs

@1GHz and 250km/h

- Doppler spread of approx. 500Hz
- Coherence time of approx. 2ms
- “Burst” packet 577µs not <<2ms => sync midamble

training sequence

HISTORIC REVIEW

2) The First Mobiles

1992

Motorola International 1000

1993

Ericsson GH 172

1999

Nokia 7110 mit WAP-Browser

GSM – **G**od **S**end us **M**obiles


Don't Text
& Drive

3) First Network Deployments

TECHNISCHE UNIVERSITÄT DRESDEN

vodafone chair

Antenna

1993

MSC Leipzig

1998

1998

Bayern,

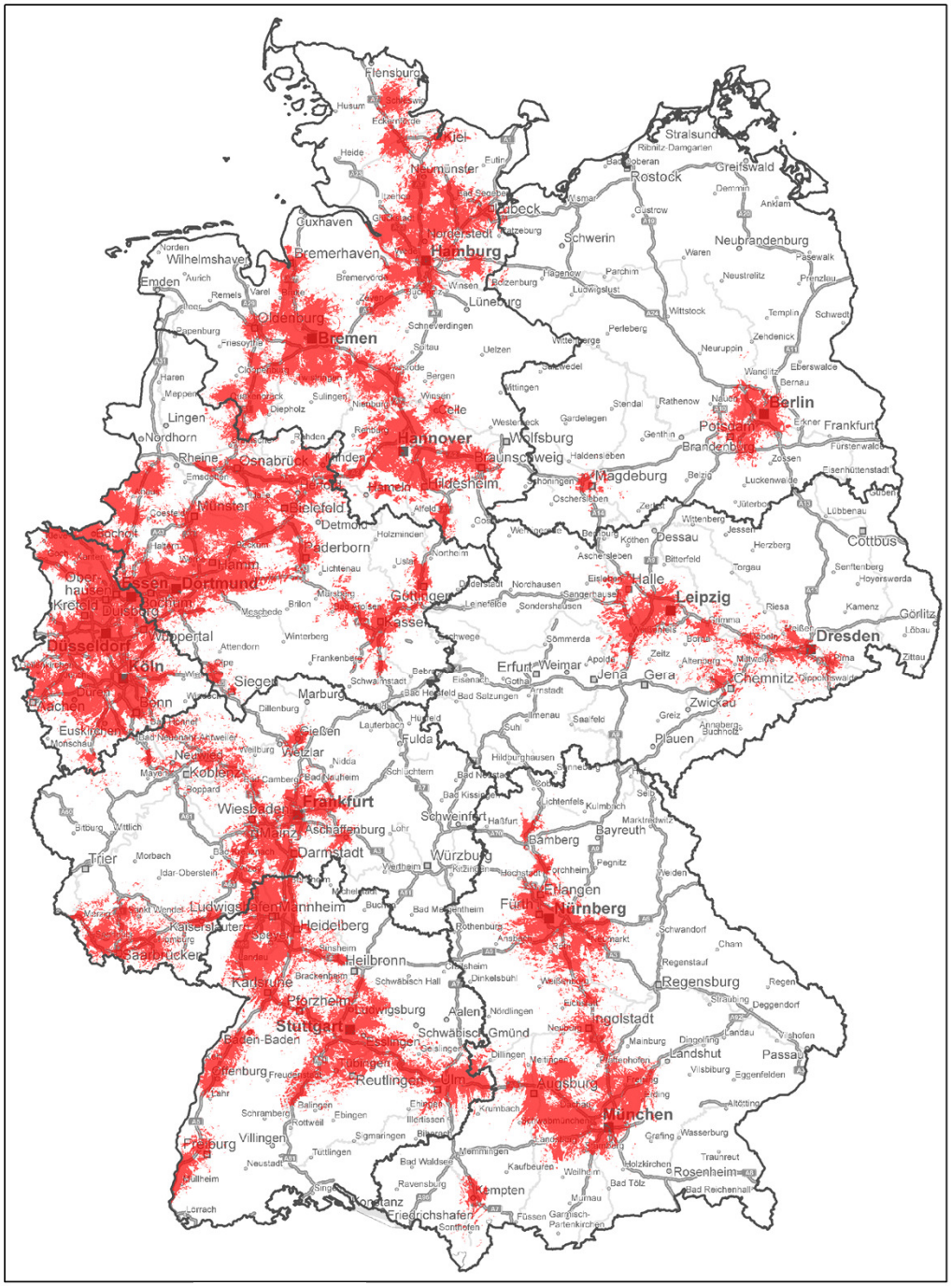
1.800m Wendelstein

Siemens GSM BSC

1999

Mid

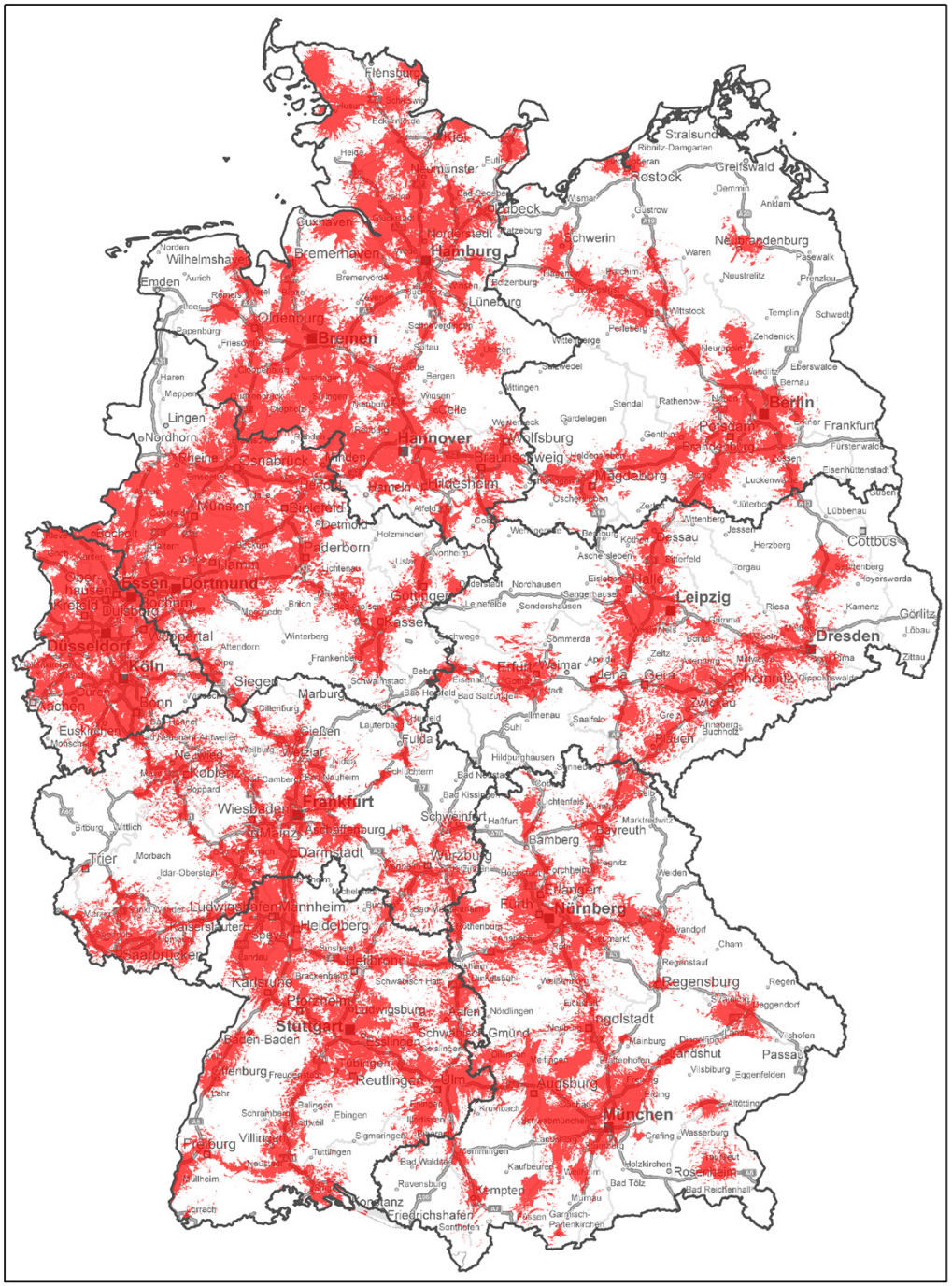
1992



GSM-Versorgung, Mitte 1992

vodafone

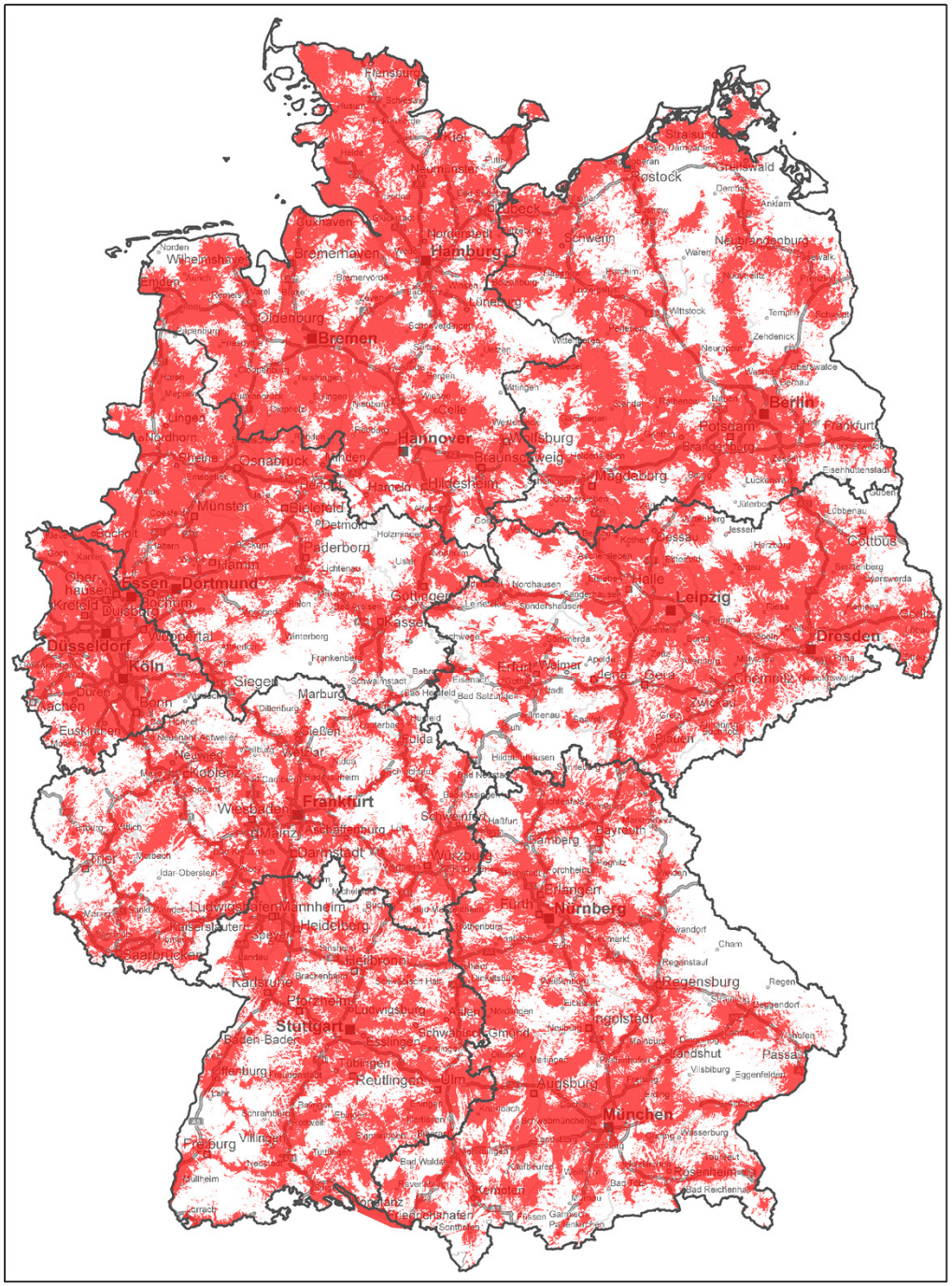
1992



GSM-Versorgung, Stand 1992

vodafone

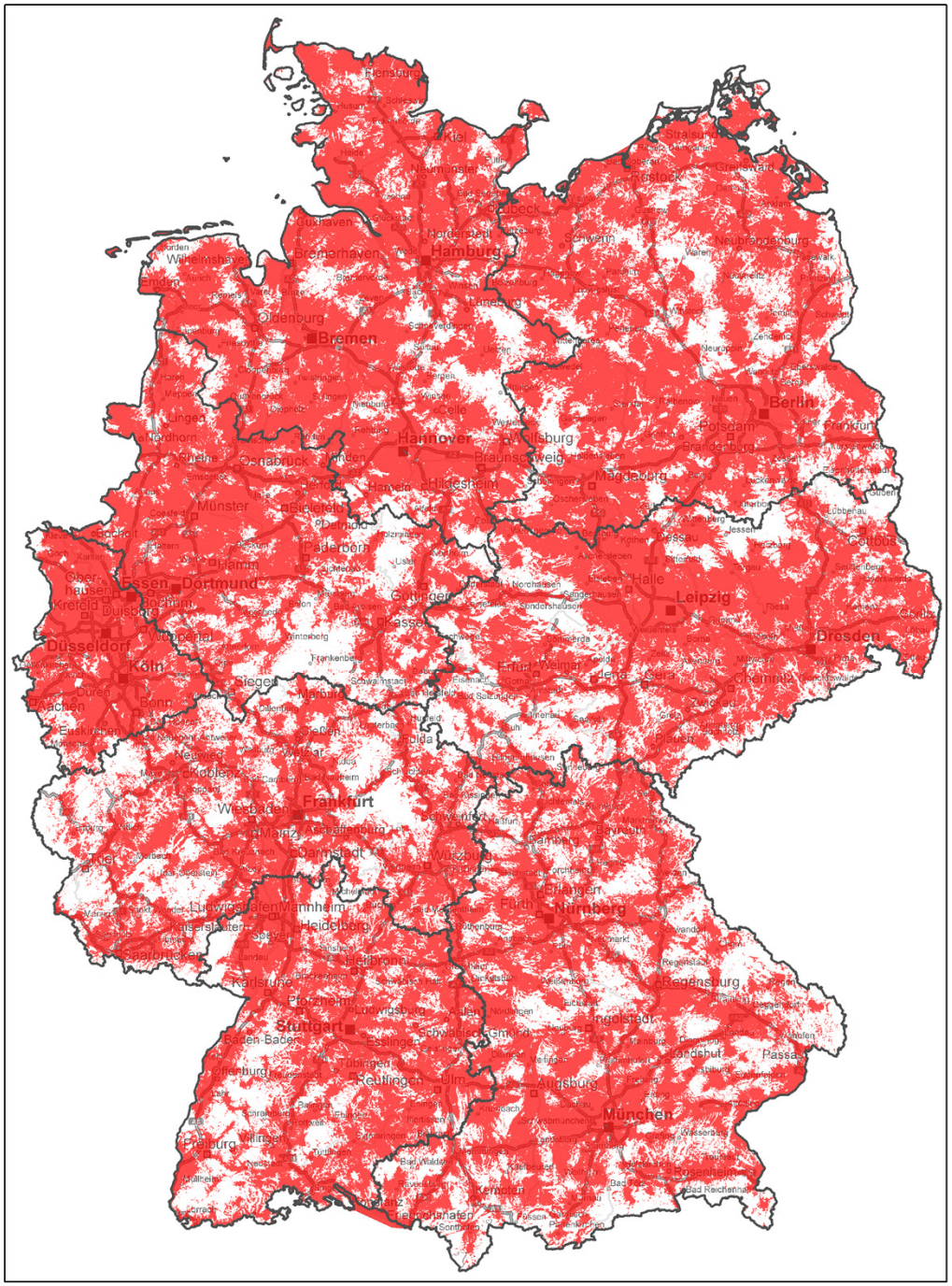
1993



GSM-Versorgung, Stand 1993

vodafone

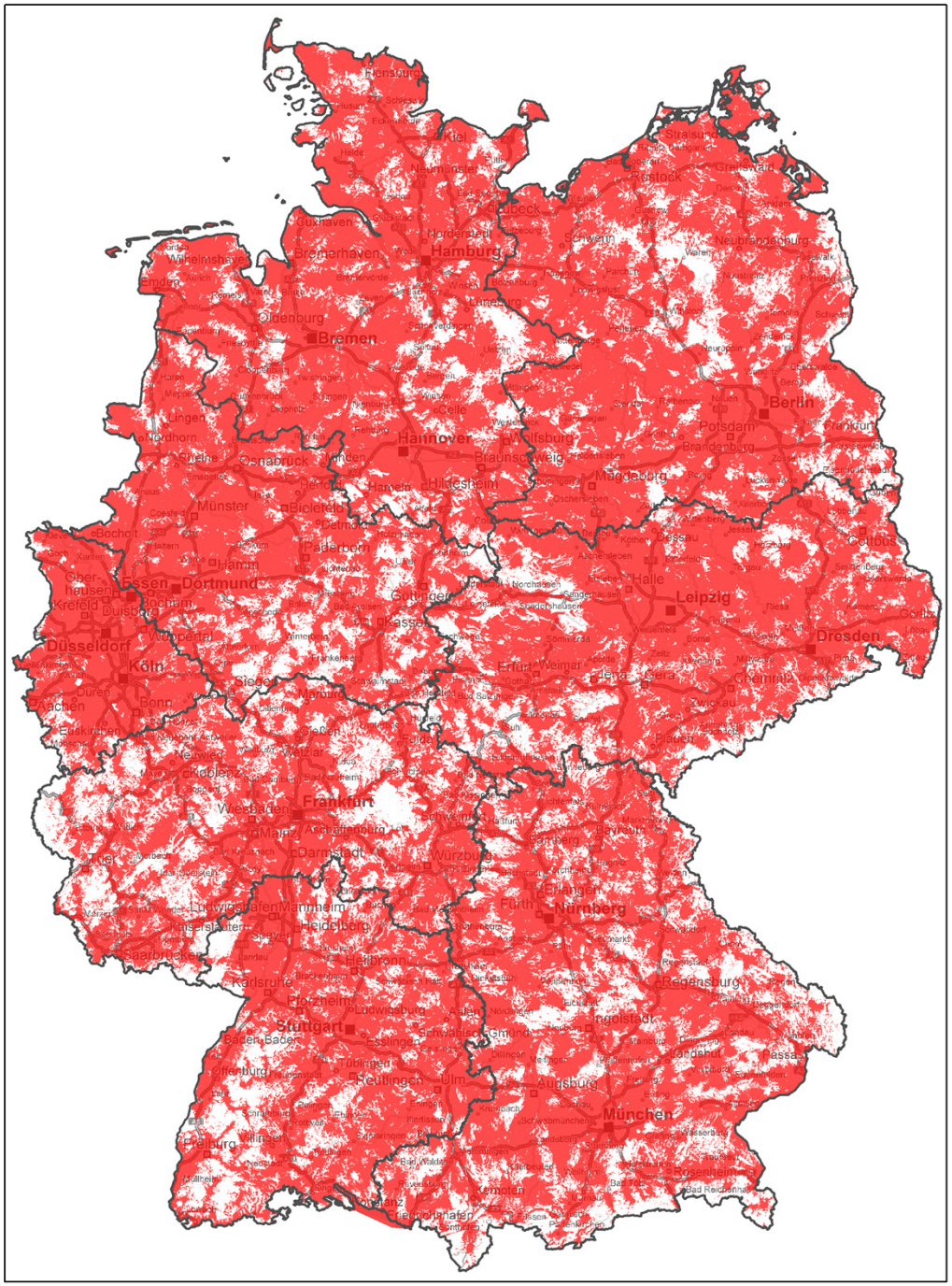
1994



GSM-Versorgung, Stand 1994

vodafone

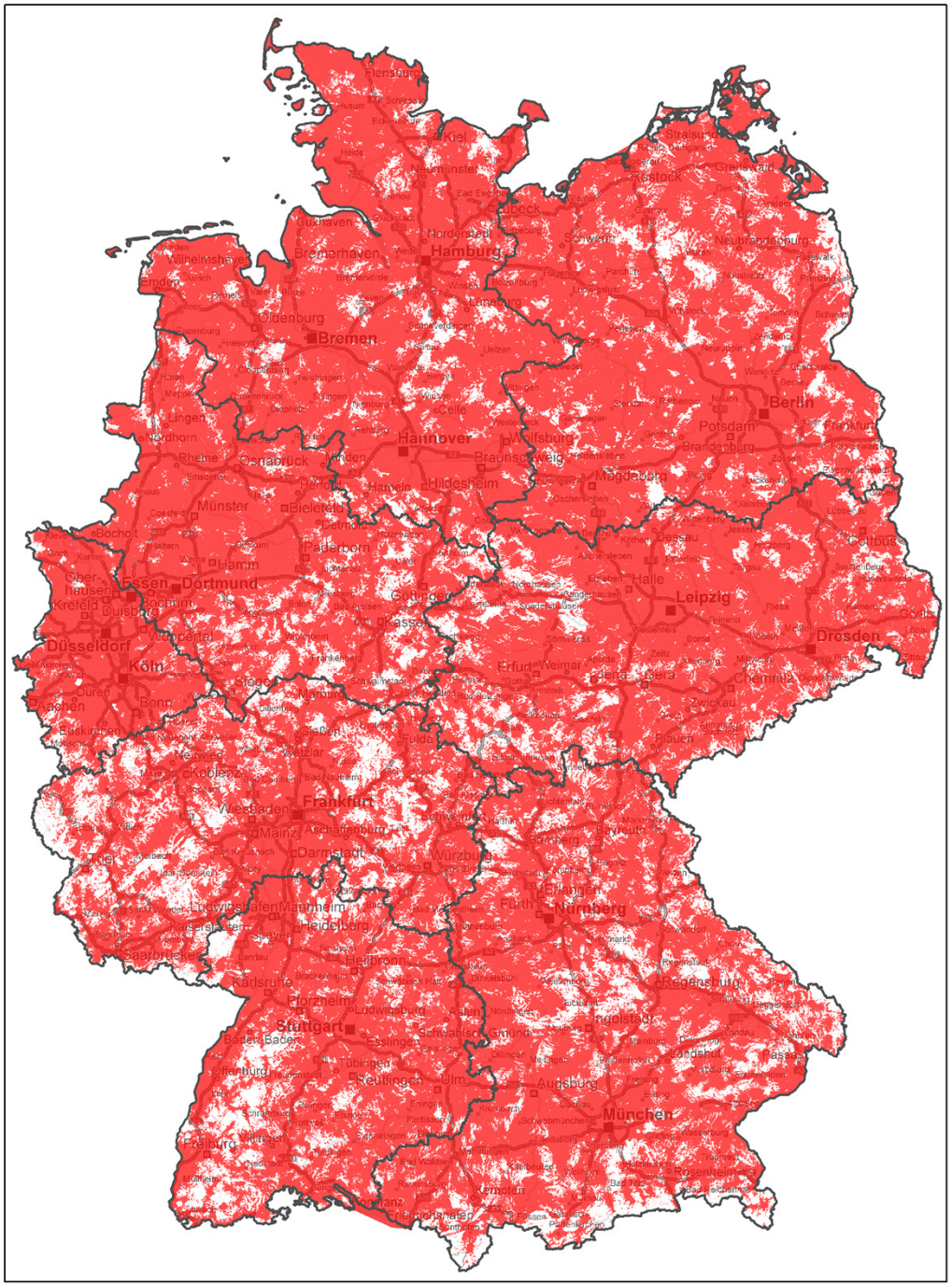
1995



GSM-Versorgung, Stand 1995

vodafone

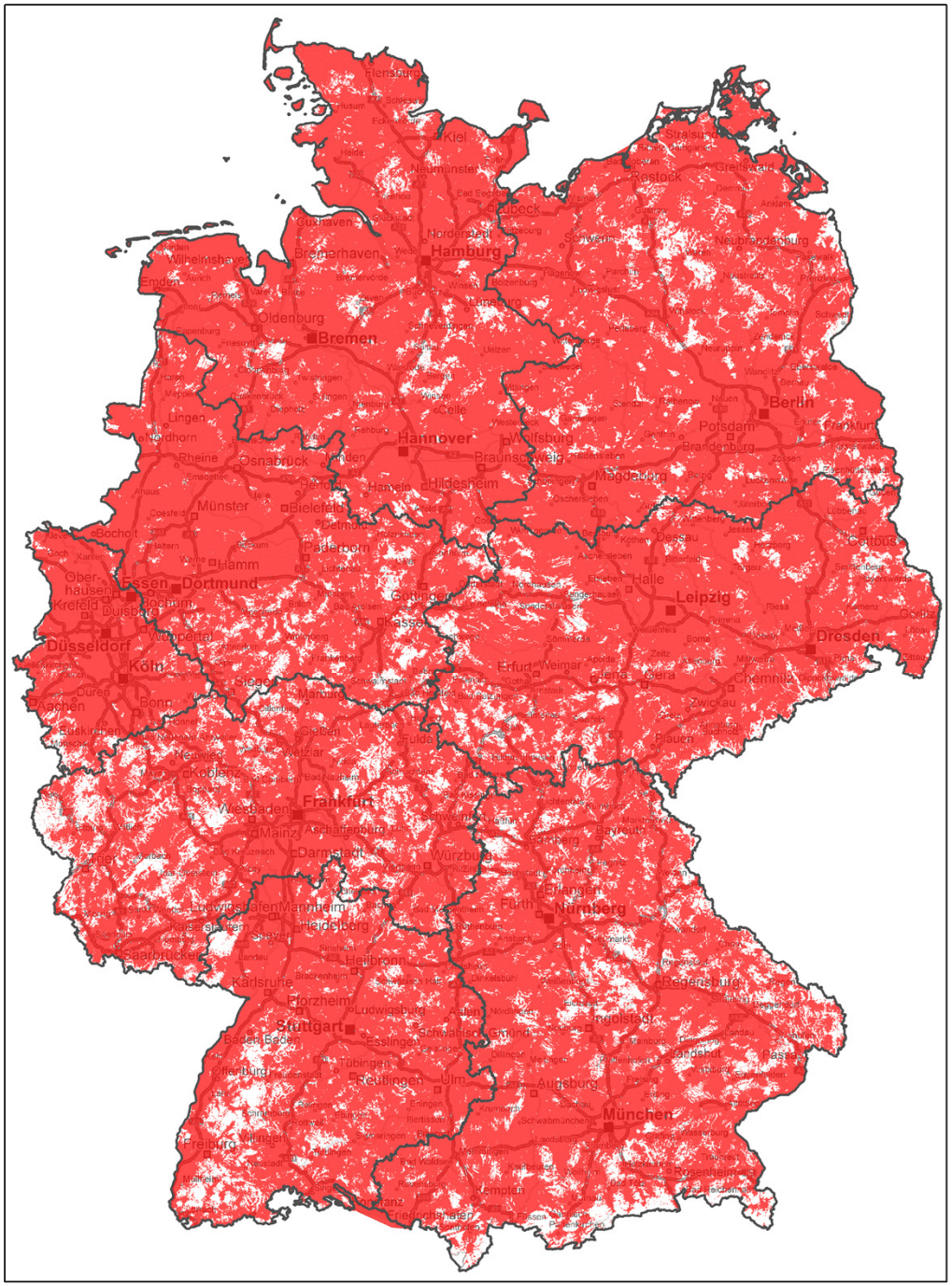
1996



GSM-Versorgung, Stand 1996

vodafone
© Vodafone GmbH

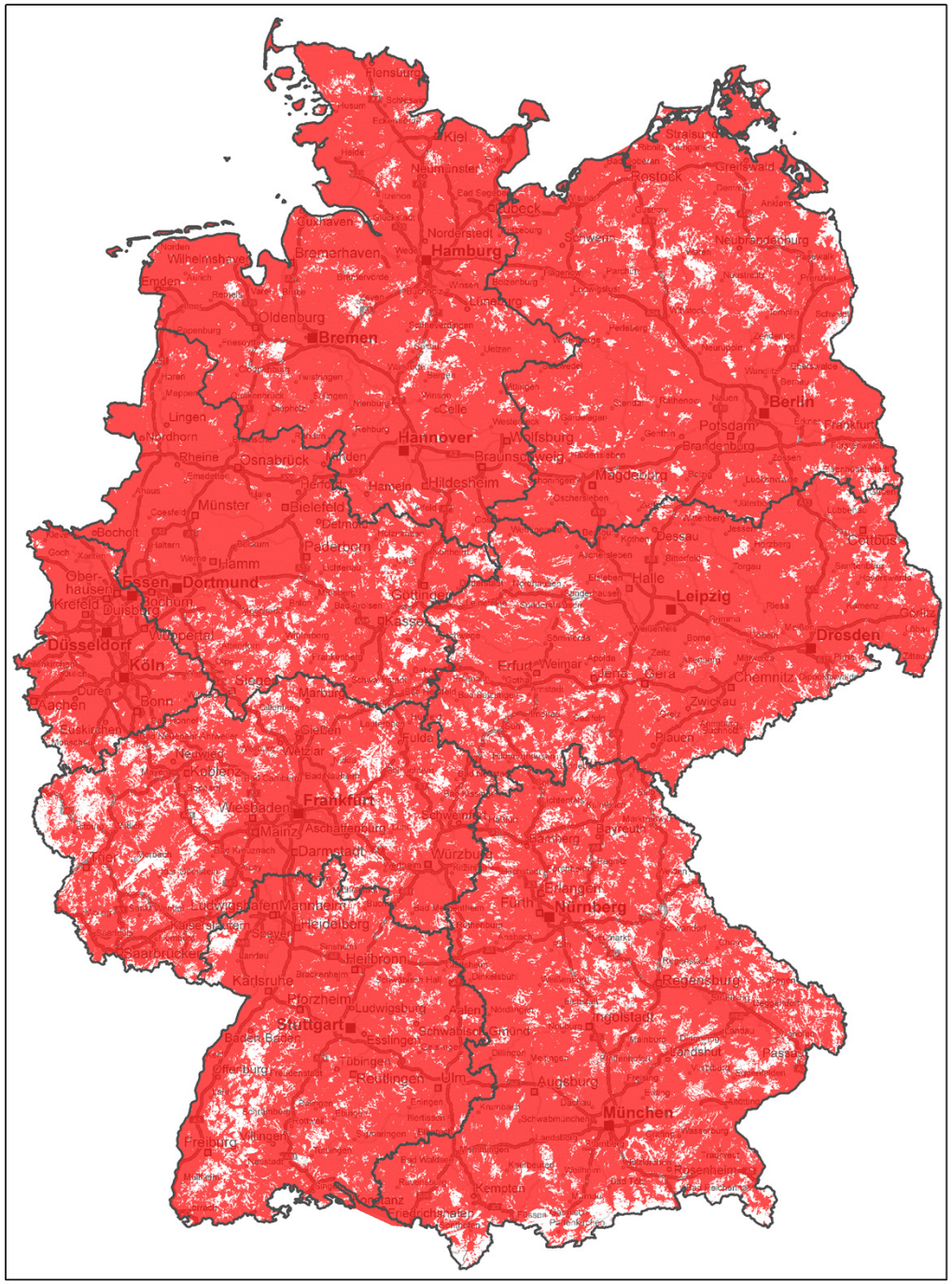
1997



GSM-Versorgung, Stand 1997

vodafone

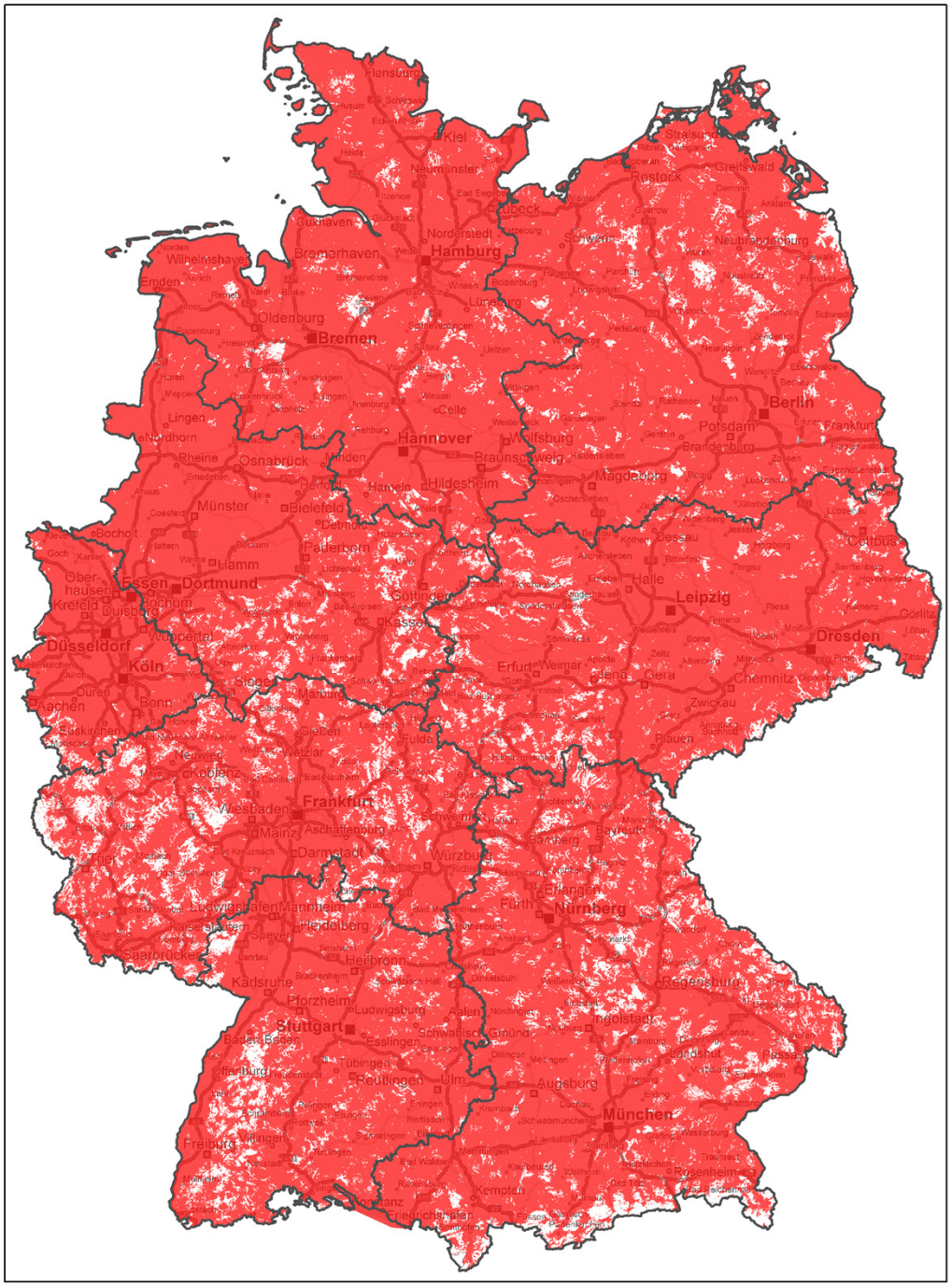
1998



GSM-Versorgung, Stand 1998

vodafone

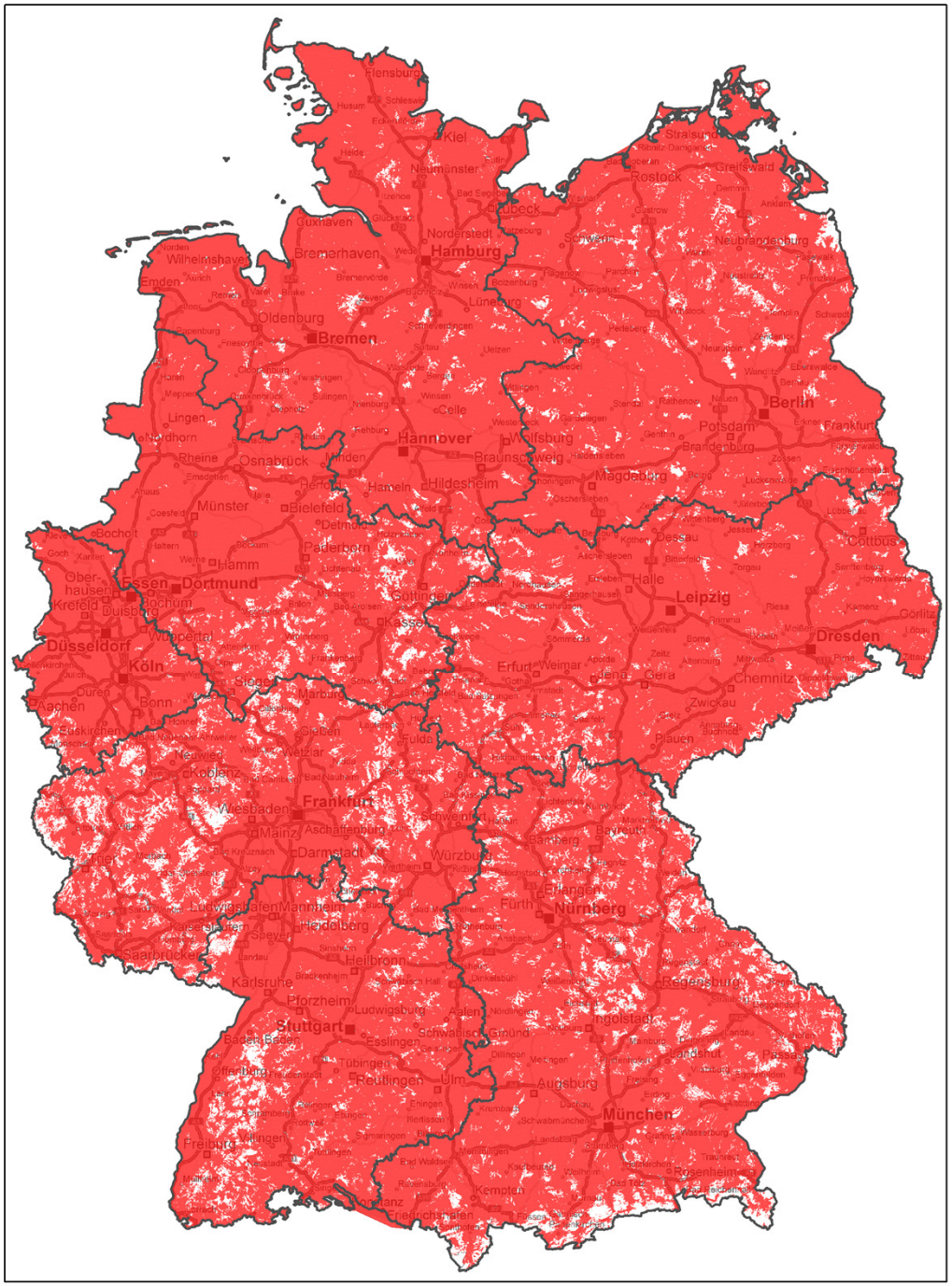
1999



GSM-Versorgung, Stand 1999

vodafone

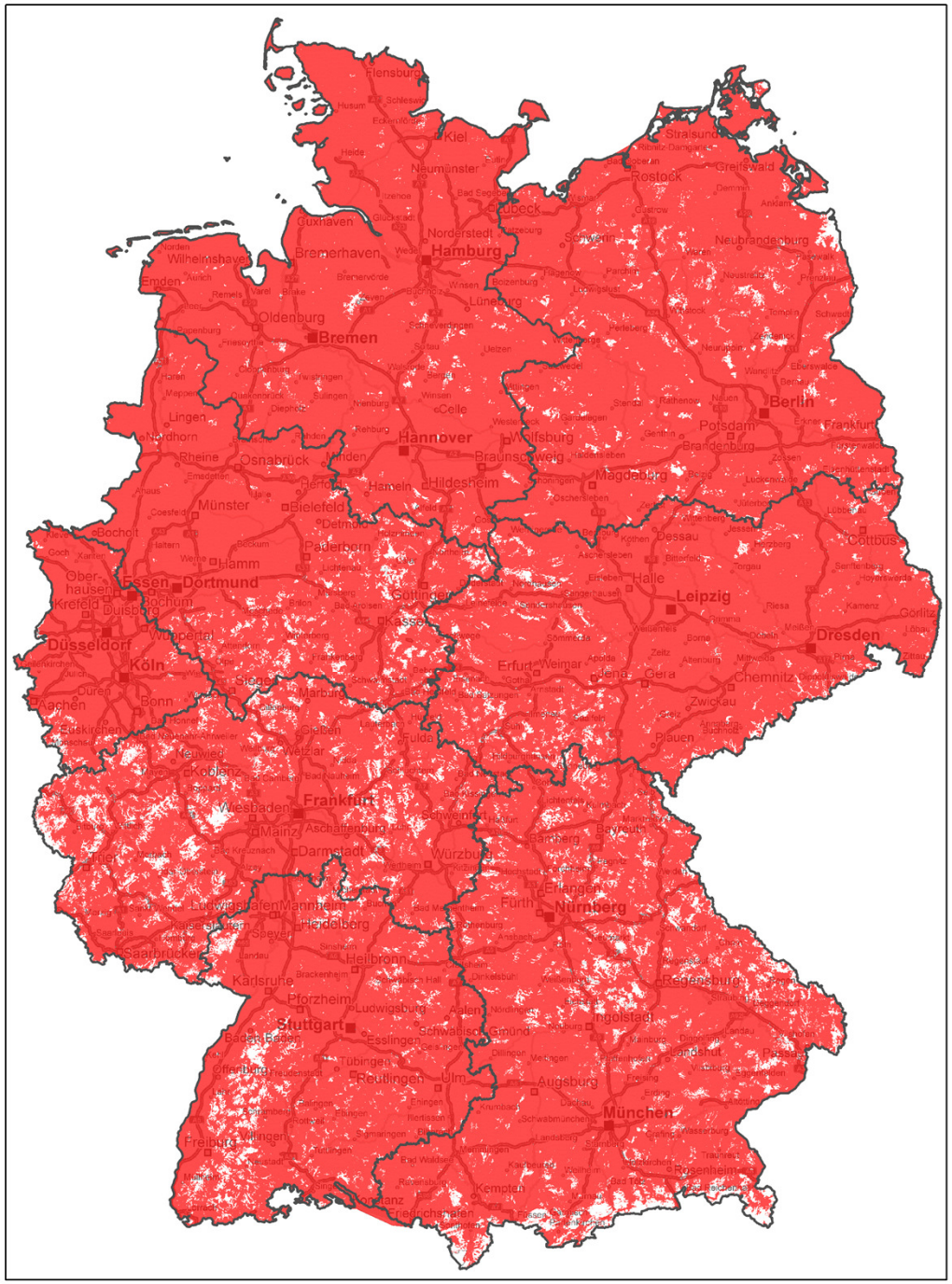
2000



GSM-Versorgung, Stand 2000

vodafone

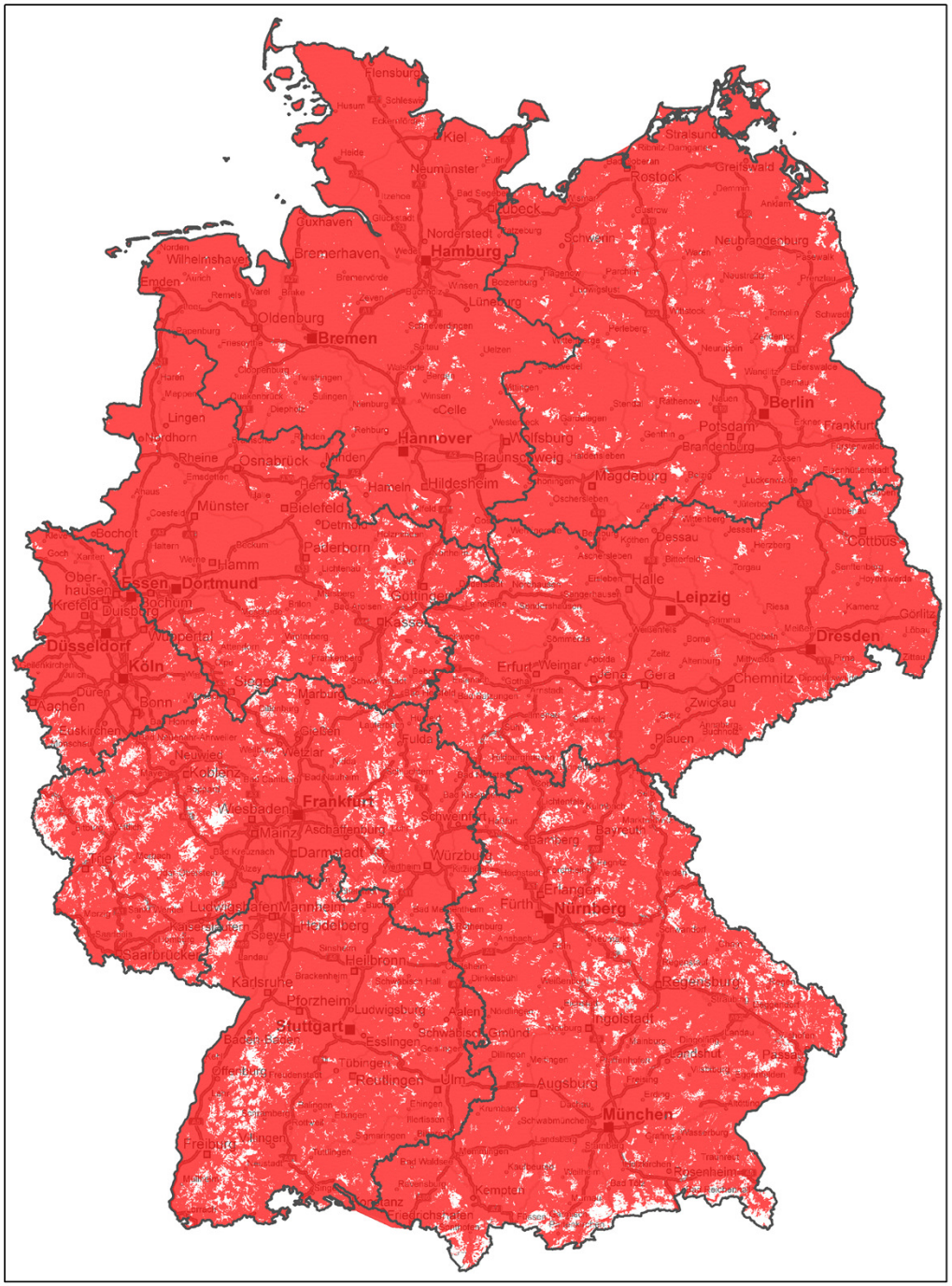
2001



GSM-Versorgung, Stand 2001

vodafone

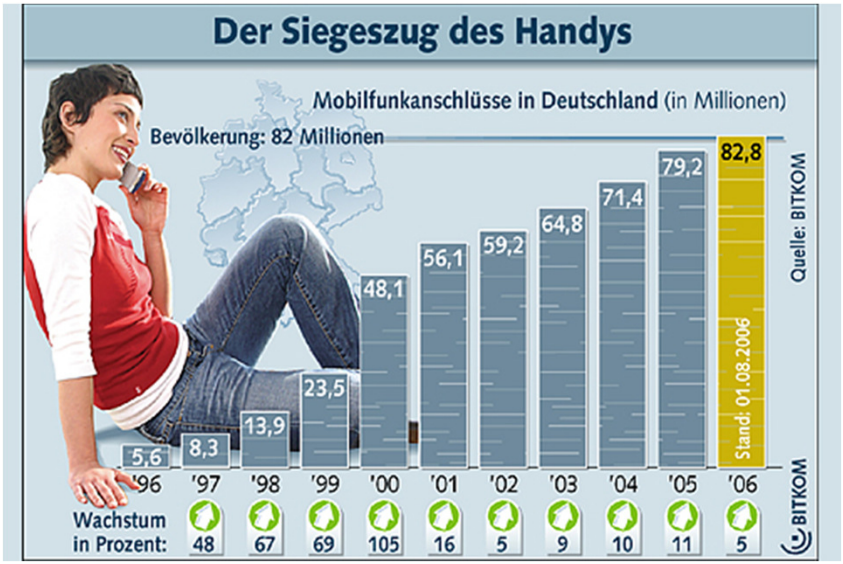
2002



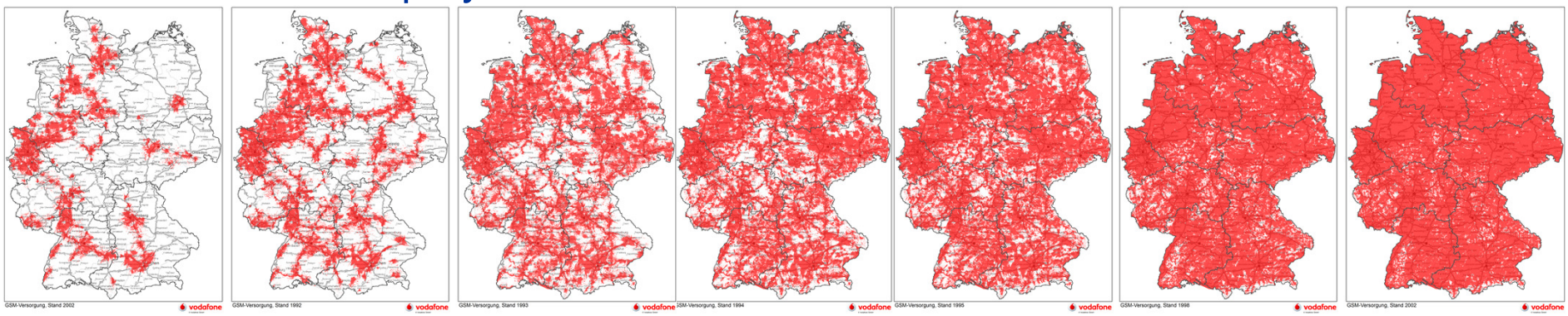
GSM-Versorgung, Stand 2002

vodafone

4) How it began in Germany

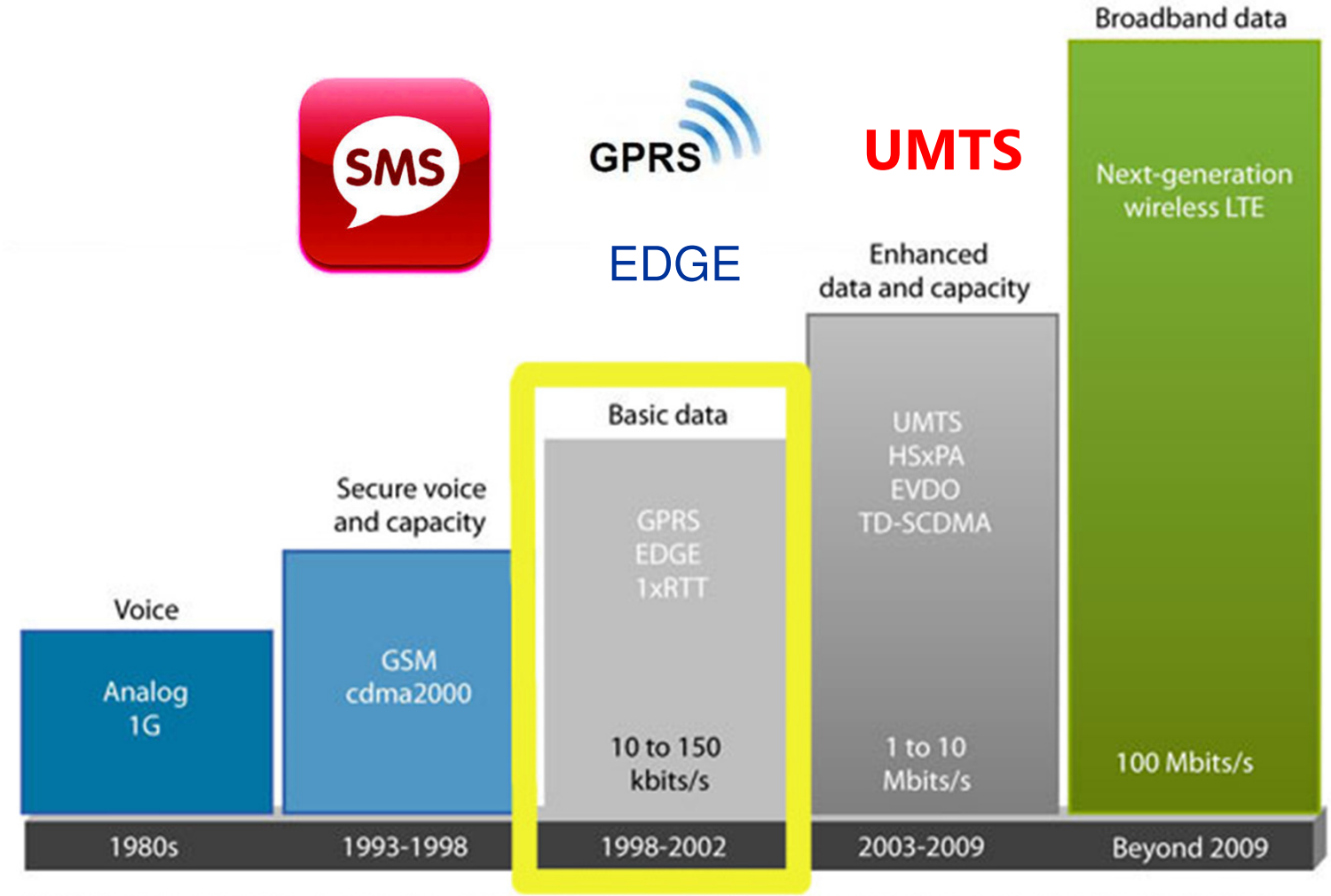


Vodafone GSM Deployment



1992 1992 1993 1994 1995 1998 2002

6) Mobile Services



Cellular services have evolved from the analog first generation to today's 3G digital phones. The next step, Long-Term Evolution (LTE), promises downlink speeds of up to 100 Mbits/s and uplink speeds of up to 50 Mbits/s.

GSM: Where It Began

Cellular Roadmap

TECHNISCHE UNIVERSITÄT DRESDEN

vodafone chair

2G – 1992
Voice
Messages

3G – 2002
+ Data
+ Positioning

4G – today
+ Video Conferencing
+ 3D Graphics

5G – 2020
+ Control
+ Things 2.0

Thanks to Vodafone for 16 years of continued support *!*

www.vodafone-chair.com